Appendix A
ATHENA Input Data Requirements

CONTENTS

TABLES

Appendix A
ATHENA Input Data Requirements

1 Introduction

This appendix completely describes data deck organization and data card requirements for all problem types allowed in ATHENA.

1.1 Control Format

Input is described in terms of input records or cards, where an input record or card is an 80-character record. Punched cards are nearly obsolete and one would be hard-pressed to find a key punch machine at most installations. Now, data are normally entered from interactive terminals, personal computers, or workstations, and the input usually exists only as disk files or is archived on tape. Data are usually viewed as lines on a CRT screen or lines of printed output. Nonetheless, the word card in used extensively in this input description to mean an input record.

ATHENA attempts to read a 96-character record. If the actual input record is smaller, blank characters are added to the end of the input record to extend it to 96 characters. Each 96-character input record, preceded by a sequential card number starting at one and incrementing by one, is printed as the first part of a problem output. Only the first 80 characters are used for ATHENA input; the additional 16 columns are for use with editors or utility programs such as UPDATE.

Most interactive editors allow the input of at least 80-character records. With many terminals allowing only 80 characters per line, it is convenient to limit the data record to 72 characters so that the data and editor-supplied line numbers fit on one line (eight columns for line number and separator, 72 columns of data). Some editors provide for the optional storing of editor line numbers following the data portion of the record. If the data field is 72 columns, the line numbers might be stored in columns 73 to 80. These line numbers will be processed by ATHENA as input, since ATHENA uses the first 80 characters. To avoid this, either request the editor to store line numbers starting at character position 81, put a terminating character before the line number, or do not store the line numbers. The line numbers, if saved, are listed in the output echo of the input data.

If the UPDATE program is used to maintain the input deck, the update command must be used to specify that the card data are 80 columns instead of the default of 72.

1.2 Data Deck Organization

A ATHENA problem input deck consists of at least one title card, optional comment cards, data cards, and a terminator card. A list of these input cards is printed at the beginning of each ATHENA problem. The order of the title, data, and comment cards is not critical except that only the last title card and, in the case of data cards having duplicate data card numbers, only the last data card is used. We recommend that for a base deck, the title card be first, followed by data cards in card number order.

Comment cards should be used freely to document the input. For parameter studies and for temporary changes, a new title card with the inserted, modified, and deleted data cards and identifying comment cards should be placed just ahead of the terminating card. In this manner, a base deck is maintained, yet changes are easily made.

When card format punctuation errors, such as an alphanumeric character in numeric fields are detected, a line containing a caret (^) located under the character causing the error and a message giving the card column of the error are printed. An error flag is set such that input processing continues, but the ATHENA problem is terminated at the end of input processing. A standard ATHENA error message (error message preceded by ********) is printed if a card error is found. Usually a card error will cause additional error comments to be printed during further input processing when the program attempts to process the erroneous data.

1.3 Title Card

A title card must be entered for each ATHENA problem. A title card is identified by an equal sign (=) as the first nonblank character. The title (remainder of the title card) is printed as the second line of the first page following the list of input data. If more than one title card is entered, the last one entered is used.

1.4 Comment Cards

An asterisk (*) or a dollar sign ($) appearing as the first nonblank character identifies the card as a comment card. Blank cards are treated as comment cards. The only processing of comment cards is the printing of their contents. Comment cards may be placed anywhere in the input deck except before continuation cards.

1.5 Data Cards

Data cards may contain varying numbers of fields that may be integer, real (floating point), or alphanumeric. Blanks preceding and following fields are ignored.

The first field on a data card is a card identification number that must be an unsigned integer. The value for this number depends upon the data being entered and will be defined for each type. If the first field has an error or is not an integer, an error flag is set. Consequently, data on the card are not used, and the card will be identified by the card sequence number in the list of unused data cards. After each card number and the accompanying data are read, the card number is compared to previously entered card numbers. If a matching card number is found, the data entered on the previous card are replaced by data from the current card. If the card being processed contains only a card number, the card number and data from the last previous card with that card number are deleted. Deleting a nonexistent card is not considered an error. If a card causes replacement or deletion of data, a statement is printed indicating that the card is a replacement card.

Comment information may follow the data fields on any data card by beginning the comment with an asterisk (*) or dollar ($) sign.

A numeric field must begin with either a digit (0 through 9), a sign (+ or -), or a decimal point (.). A comma or blank (with one exception, subsequently noted) terminates the numeric field. The numeric field has a number part and optionally an exponent part. A numeric field without a decimal point or an exponent is an integer field; a number with either a decimal point, an exponent, or both is a real field. A real number without a decimal point (i.e., with an exponent) is assumed to have a decimal point immediately in front of the first digit. The exponent part denotes the power of ten to be applied to the number part of the field. The exponent part has an E or D, a sign (+ or -), or both followed by a number giving the power of ten. These rules for real numbers are identical to those for entering data in FORTRAN E or F fields except that no blanks (with one exception) are allowed between characters to allow real data written by FORTRAN programs to be read. The exception is that a blank following an E or D denoting an exponent is treated as a plus sign. Acceptable ways of entering real numbers, all corresponding to the quantity 12.45, are illustrated by the following six fields:

12.45, +12.45, 0.1245+2, 1.245+1, 1.245E 1, 1.245D+1 .

When entering a decimal zero for either an integer or floating point quantity, the zero can be written in either form. Thus a floating point zero can be entered simply as 0 without a decimal point.

Alphanumeric fields have three forms. The most common alphanumeric form is a field that begins with a letter and terminates with a blank, a comma, or the end of the card. After the first alphabetic character, any characters except commas and blanks are allowed. The second form is a series of characters delimited by quotes (“) or apostrophes (’). Either a quote or an apostrophe initiates the field, and the same character terminates the field. The delimiters are not part of the alphanumeric word. If the delimiter character is also a desired character within the field, two adjacent delimiting characters are treated as a character in the field. The third alphanumeric form is entered as nHz, where n is the number of characters in the field, and the field starts at the first column to the right of H and extends for n columns. With the exception of the delimiters (even these can be entered if entered in pairs), the last two alphanumeric forms can include any desired characters. In all cases, the maximum number of alphanumeric characters that can be stored in a word is eight. If the number of characters is less than eight, the word is left justified and padded to the right with blanks. If more than eight characters are entered, the field generates as many words as needed to store the field, eight characters per word, and the last word is padded with blanks as needed. Regardless of the alphanumeric type, at least one blank or comma must separate the field from the next field.

Most computers (e.g., workstations, CRAY, and IBM) hold only eight characters per word. All alphanumeric words required by ATHENA, such as components types, system names, or processing options, have thus been limited to eight characters. We highly recommend that the user limit all other one-word alphanumeric quantities to eight characters so that input decks can be easily used on all computer versions. Examples of such input are alphanumeric names entered to aid identification of components in output edits.

The total number of words on all cards may not exceed 2,097,151. The largest card number allowed is 536,870,911.

1.6 Continuation Cards

A continuation card, indicated by a plus sign (+) as the first nonblank character on a card, may follow a data card or another continuation card. Fields on each card must be complete, that is, a field may not start on one card and be continued on the next card. The data card and each continuation card may have a comment field starting with an asterisk (*) or dollar ($) sign. No card number field is entered on the continuation card, since continuation cards merely extend the amount of information that can be entered under one card number. Deleting a card deletes the data card and any associated continuation cards. The total number of words on a card and its continuation cards may not exceed 2,047.

1.7 Terminator Cards

The input data are terminated by a slash or a period card. The slash and period cards have a slash (/) and a period (.), respectively, as the first nonblank character. Comments may follow the slash and period on these cards.

When a slash card is used as the problem terminator, the list of card numbers and associated data used in a problem is passed to the next problem. Cards entered for the next problem are added to the passed list or act as replacement cards, depending on the card number. The resulting input is the same as if the slash card was removed from the input data. If a slash card terminates the replacement cards, the process is repeated, with the original problem cards plus the cards between the first slash card and the second slash card plus the cards between the second slash card and the next termination card being added to the passed list. This continues until a period card is reached.

When a period card is used as the problem terminator, all previous input is erased before the input to the next problem is processed.

1.8 Sequential Expansion Format

Several different types of input are specified in sequential expansion format. This format consists of sets of data, each set containing one or more data items followed by an integer. The data items are the parameters to be expanded, and the integer is the termination point for the expansion. The expansion begins at one more than the termination point of the previous set and continues to the termination point of the current set. For the first set, the expansion begins at one. The termination points are generally volume, junction, or mesh point numbers, and always form a strictly increasing sequence. The input description will indicate the number of words per set (always at least two) and the last terminating point. The terminating point of the last expansion set must equal the last terminating point. Two examples are given.

The first example is for the volume flow areas in a pipe component; the format is two words per set in sequential expansion format for nv sets. Using the number of volumes in the pipe (nv) as 10, the volume flow areas could be entered as

0010101 0.01,10 .

In this case, the volume flow areas for volumes 1 through 10 have the value 0.01.

The second example shows how the pipe volume friction data could be input. The input consists of three words per set for nv sets. The three words designate the wall roughness, hydraulic diameter (input of zero causes the code to calculate it), and volume number. Possible data might be

0010801 1.0-6,0,8 1.0-3,0,9

0010802 1.0-6,0,10 .

Here, volumes 1 through 8 and 10 have the same values, and volume 9 has a different value.

1.9 Upper/Lower Case Sensitivity

Historically, computer systems allowed only upper case alphabetic characters. Accordingly, the following input descriptions use upper case for required input, e.g., SNGLVOL, 1.25E5. Now, many systems have upper and lower case alphabetic characters, and some applications are case sensitive, others not. At the INEEL, required input must be in lower case, and the user should check the requirements at other installations. At installations with both upper and lower case capability, there are utilities and editors that can easily switch alphabetic characters to the desired case.

1.10 Data Card Requirements

In the following description of the data cards, the card number is given with a descriptive title of the data contained on the card. Next, an explanation is given of any variable data that are included in the card number. Then, the order of the data, the type, and the description of the data item are given. The type is indicated by A for alphanumeric, I for integer, and R for real.

2 Miscellaneous Control Cards

2.1 Card 1, Developmental Model Control

This card has been added to the code for the convenience of developers in testing model improvements or new models. This card is not a standard input feature of the code. The description of this card has been added to the input requirements because several laboratories are receiving test versions to assist in the development and testing of the code. Anyone using this card must realize that they are selecting experimental options still under development. Furthermore, these options may change more frequently than the revision of this input manual. Thus, before using the options, users should obtain the brief listing of current options from the code (described below) and verify those descriptions against this manual.

The purpose of this card is to allow developers and analysts to quickly test new models by activating or deactivating a model through simple input instead of program modification, compilation, and loading. Ninety-nine logical variables having only false or true values are provided and defined at the start of program execution as false. This input sets the logical variables to true or resets them to false at the beginning of a new problem or at any restart. Fortran IF statements added as part of the experimental coding activate or deactivate models based on the values of the logical variables.

As described above, up to 99 options can be defined and the options are identified with a number from 1 through 99. Which options are defined and what they control are very much version dependent. The usual practice is to enter the option capability using a currently unused option number as the new model or improvement is first coded. During further development and testing, the model may change and the effect of the option can change in a manner ranging from large to subtle. When the model has been completed or even abandoned, the production version of the model is coded and the option capability is removed. The option number is then available for reuse with a completely different model. Thus, the options are version dependent as to what option numbers are in use, what models they control, and the particular features of the models. Accordingly, these options should be used only by those in direct contact with the developers.

Each current option is described below. In light of the discussion above, the user should verify that the code version being used corresponds to this description. Programmers using this option feature are asked to include coding that issues error messages when unused options are selected and to issue a brief statement of the purpose of selected options. Remember, however, that all coding associated with these options is experimental and these output conventions may not be thoroughly checked.

Up to 99 numbers consisting of 0 or any of the currently available option numbers may be entered on this card. A positive nonzero number, n, activates Option n by setting the logical variable n to true; a negative nonzero number, -n, deactivates Option n by setting the logical variable n to false. Attempting to activate an unused option is an error, and attempting to deactivate an already inactive option or an unused option is also an error. Adding options or deactivating options is allowed at a restart; the previously defined options will remain. The status of the options is printed in any NEW or RESTART problem containing this card or a RESTART problem in which the restart point had an option selected. The printout includes a listing of the 99 option numbers and a false (option not selected) or a true (option selected) value plus the brief description of each selected option.

The number 0 is not an option number but may be entered to force the brief descriptions of all available options to be printed regardless of whether they are active. The 0 input should be used only once to observe the available options and then removed so that the list better emphasizes the selected options.

The number 100 is an option that is always active [i.e., the logical variable n (=100) is always true] and can be used to activate coding which is being tested by a developer. The number 100 should not be entered on a card; if it is entered, an input error will occur.

W1-100(I) Zero or an available option number as described above.

Option 0. This option prints all option descriptions.

Option 1. This options adds viscous stress terms to the momentum equations for the semi-implicit scheme using the 1D components without the simvisc 'ifdef' option. For the semi-implicit scheme, the simvisc option means the momentum flux is calculated using the volume velocity times the donored volume velocity; without this option, the momentum flux is calculated using the volume velocity plus the artificial viscosity.

Option 2. This option sets the interfacial mass transfer to zero and the direct heating heat transfer coefficient to 10^5 W/m^3·K.

Option 3. This option uses consistent noncondensables choking. This change makes the junction sound speed calculation method consistent with the volume sound speed calculation method. The coding for this option is not complete.

Option 5. This option uses the old EPRI interphase friction.

Option 6. This option uses static quality instead of void fraction for the partitioning of non-correlation wall heat transfer options 2xxx, 3xxx, and 4xxx, when a boundary volume is present.

Option 7. This option reduces the interface drag and the virtual mass. It is used for the gravity wave calculations.

Option 8. This option provides time step control based on the change in void fraction and is designed to limit the time step when the void fraction in any cell is decreasing rapidly such as during periods of condensation. The time step will be repeated if the decrease in void fraction in any hydrodynamic volume is considered too large. The time step will be repeated if the new void fraction is less than 0.001 and the old void fraction was greater than 0.01. The time step will also be repeated if the new void fraction is between 0.01 and

0.10 and the change in void fraction during the time step exceeds 20% of the new void fraction. If the new void fraction exceeds 0.10, the time step will be repeated if the change exceeds 50% of the new void fraction. The time steps are repeated only when the void fraction is decreasing. This option is being tested in conjunction with Options 10 and 12 for improved performance at low pressures.

Option 9. This option provides a transition to plug flow when the vapor/gas velocity exceeds the criterion for transition from stratified flow in horizontal geometries. The need for this change occurs during the reflood phase in the horizontal core of the Hanford N-Reactor. The process tubes in the core region are long and have a small diameter. As subcooled coolant enters the process tubes, high condensation occurs that results in local depressurization and high vapor/gas velocities towards the condensation site. Instabilities occur that eventually cause the code to fail. This changes introduces a plug flow model that limits condensation to a value that is just large enough to condense all the vapor that can flow at the critical velocity, utilizing the full channel cross-sectional area. The critical velocity is the velocity large enough to cause transition from a stratified flow condition. The concept behind this model is that condensation lowers the local pressure and draws in steam which pushes the liquid into a plug. The area of the plug limits condensation and reduces vapor/gas flow which causes a return to stratified flow.

Option 10. This option provides time step control based on change in pressure within a hydrodynamic volume. This change causes the code to repeat a time step if the change in pressure during a time step exceeds the old time value, the new time value, or 50,000 Pa. This time step control allows the pressure to change by no more than a factor of two during a time step. This change generally causes the code to run slower but more reliably. With this change activated, the code will more accurately track pressure waves and oscillations but may cause certain problems to run unacceptably slowly. This option has no effect if Option 8 is not selected.

Option 11. This option modifies the coding of light water (h2o) for metastabel states near the critical point useing linear interpolation rather than cubic interpolation between points in the thermodynamic property file for specific volume and isothermal compressibility. This option also modifies the coding of hydrogen (h2), potassium (k), helium (he), nitrogen (n2), sodium (na), soduim-potassium (nak), lithium-lead (lipb), ammonia (nh3), glycerol (glycerol), blood (blood), and carbon dioxide (co2) as is done for light water (h20).

Option 12. This option provides a user controlled (on/off) water packer developed for horizontal reactors such as the Hanford N-Reactor. The interfacial friction coefficient term for the momentum equation, C_i, is adjusted as a function of vapor void fraction. For void fractions of 0.001 or less, C_i is forced to an arbitrarily large value of 10^{10}. For void fractions greater than 0.01, the regularly calculated C_i is used. For void fractions between 0.001 and 0.01, a cubic interpolation scheme is used to adjust C_i between the calculated value and $10^{10} N \cdot s^2/m^5$. As a cell is calculated to fill with liquid and the calculated cell pressure rises, the lower inertia vapor is the phase first to respond, either moving on to the next cell or moving back to an upsteam cell. The effect of this model is that, as the void fraction decreases, the interfacial drag is increased, thus allowing the moving vapor to either drag liquid on to the next cell or impede the incoming liquid from an upstream cell. In either case, the model eases the overfilling and overpressurization of the cell.

Option 13. This option activates vertical stratification changes.

Option 14. This option turns off constitutive relations and should only be used for testing advancement of the basic advancement scheme for two-phase conditions. Do not use for single phase conditions.

Option 15. This option uses the minimum Courant limit for all the volumes in the time step control.

Option 17. This option allows the code to run up to the Courant limit (option 60) with a multiplication factor of four instead of two and a reduction factor of 0.25 instead of 0.5 used in the mass error check for the time step control.

Option 18. This option adds the sharp interface and reverse void profile logic from RELAP5/MOD2.5.

Option 19. This option uses the Bestion correlation (in RELAP5/MOD2.5) rather than the EPRI correlation (in ATHENA) for bundles (when volume flag b = 1).

Option 20. Changes the two-phase region of the modified Henry-Fauske critical flow model (option 53). This option has no effect if option 53 is not selected. This option, when activated, is used by both the semi-implicit solution scheme and the nearly-implicit solution scheme.

Option 21. <u>Do not use.</u> Presently option only acquires additional storage arrays for testing numerical techniques.

Option 23. This option selects a Godunov boron transport algorithm that greatly reduces the numerical diffusion of boron compared to the standard algorithm.

Option 24. This option selects a Savannah River Laboratory (SRL) subcooled boiling model.

Option 25. This option linearizes the interfacial heat transfer for the nearly-implicit scheme.

Option 28. This option applies modeling that results in large time steps being allowed for cases of intense oxidation at low pressure ($< 2 \times 10^5$ Pa).

Option 32. This option activates the water stretch logic.

Option 33. This option uses border profile LU matrix routines for solution of hydrodynamic equations. In the future, this option will be removed since the border profile LU matrix routines are the default.

Option 34. This option selects a generalized minimum residual iterative solver instead of border profile LU matrix routines for solution of hydrodynamic equations.

Option 35. This option selects the sparse matrix routines for solution of hydrodynamic equations. This option was the default solver for older versions of the code.

Option 36. This option limits metastable extrapolation to 50 K.

Option 37. This option turns off the umbrella model. When the umbrella model is on, an upper limit is placed on the liquid interfacial heat transfer coefficient (H_{if}) when the liquid is subcooled. The limit is umbrella shaped so as to force the coefficient to small values as the void fraction approaches 0.0 or 1.0.

Option 38 This option turns off momentum flux for the semi-implicit scheme if the amplification factor is greater than one.

Option 41. This option includes energy dissipation due to form loss (code calculated abrupt area change loss and user-specified loss).

Option 42. This option applies a stronger unchoking test for junctions with an abrupt area change.

Option 43. This option uses iteration to calculate the hydrodynamic conditions at the throat for critical flow.

Option 45. This option selects the newly developed model for condensing interphase heat transfer. The coding for this option is not complete.

Option 47. This option activates the linear implicit drags logic for the semi-implicit scheme and deactivates the linear implicit drags and implicit gravity for the nearly-implicit scheme.

Option 50. This option turns off the velocity flip-flop for all junctions.

Option 51. Normally, water packing is activated in all volumes unless specifically disabled by an input volume flag. This option disables water packing for all volumes.

Option 52. Normally, the choking model is activated for all junctions unless specifically disabled by an input junction flag. This option disables the choking model for all junctions.

Option 53. Invokes the modified Henry-Fauske critical flow model for both the semi-implicit scheme and the nearly-implicit scheme.

Option 54. This option changes the two-phase to single phase vapor/gas transition truncation limit in subroutine EQFINL.

Option 55. This option is a collection of modeling improvements designed to minimize numerical sources of oscillations for low pressure two-phase flow simulations. Specifically, this option affects: Interfacial heat transfer for annular mist, mist pre-CHF, and mist post-CHF flow regimes. The liquid-side interfacial heat transfer coefficient has been modified to replace “ad hoc” correlations with more physical models.

Option 56. This option enforces $v_g = v_f$ at $\alpha_g = 1$ in subroutine FIDIS2.

Option 57. This option modifies the phasic partitioning of the wall friction so that all of the wall friction is applied to the liquid film in the annular mist flow regime. This option is necessary to compute realistic values of the liquid film thickness.

Option 58. This option changes the smoothing used for the bubbly flow liquid interfacial heat transfer coefficient between the liquid superheat and liquid subcooled regions.

Option 60. This option modifies time step control for the Courant limit. It allows the time step to run up to the Courant time step rather than halving and doubling.

Option 61. This option further modifies constitutive relationships to reduce numerical oscillations at low pressure. Specifically, this option affects:

1. Vertical stratification, where this model is used for the purpose of defining the character of the two-phase interface to evaluate the interfacial heat transfer coefficient and interfacial area. The criteria used to determine if the interface is “stratified,” as opposed to a “normal” vertical flow regime such as slug flow, have been modified.

2. Interfacial heat transfer for bubbly and slug flow regimes, where the liquid-side interfacial heat transfer coefficient has been modified to replace “ad hoc” correlations with more physical models.

Option 62. This option uses new developed changes to the Chen F factor in prednb.

Option 64. This option uses the junction velocity based Courant limit rather than the volume based Courant limit.

Option 65. This option changes the subcooled boiling model by modifying the fraction of nucleate boiling heat flux that generates vapor when the bulk liquid is subcooled. The modification minimizes the “on/off” behavior associated with low-pressure/low-flow conditions.

Option 66. This option implements donor/acceptor differencing in vertical stratification volumes.

Option 67. This option implements velocity squared instead of velocity • velocity-donored for momentum flux.

Option 68. This option implements velocity - j times (velocity - L - velocity - K) instead of velocity • velocity-donored for momentum flux.

Option 69. This option uses a momentum flux with a donored velocity calculated using the actual donored void fraction in the numerator instead of a floored value.

Option 70. This option uses flux limited momentum flux.

Option 72. This option uses Yankee Atomic smoothing in interphase drag for vertical and horizontal flow.

Option 74. This option turns on the new interphase mass transfer model. The coding for this option is not complete.

Option 76. This option uses a modified momentum difference equation that has been cleared by voidga • voidfa • rhoga • rhofa.

Option 77. This option introduces the new geometric restriction on the stratification entrainment/pullthrough model. The coding for this option is not complete.

Option 78. This option uses a modified C-infinity definition that is dependent on Reynolds number and void fraction.

Option 80. This option adds the scaling factor to the diagonal of the Jacobian squared matrix ten times if necessary.

Option 82. This option implements the Gardner correlation ($C_0 = 1$) for tanks ($D > 0.24$ m) and low flow rates and uses the Kataoka-Ishii correlation for high up/down flows as before. This option must be used in conjunction with option 78 to be effective.

Option 83. This option turns on the new improved solution of the hydrodynamics field equations, which uses a combination of scaling and pivoting.

Option 84. This option puts in derivative of density with respect to pressure in the horizontal stratification force.

Option 85. This option puts in derivative of density with respect to pressure in the gravitational force.

Option 86. This option adds time smoothing to the thermal stratification model.

Option 87. This option uses 0.01 in the term percnt in subroutine PHANTV plus a 2% ramp.

Option 88. This option does not throw air away when steam disappears.

Option 89. This option computes the derivative of the interfacial coefficients with respect to volume void fraction for the nearly-implicit scheme.

Option 90. This option ramps interfacial mass transfer to zero based on four criteria (exponential).

Option 91. This option ramps interfacial mass transfer to zero based on four criteria (linear).

Option 95. This option reverts to the original macroscopic properties in the nearly-implicit scheme.

Option 96. This option activates the new source term methodology in the nearly-implicit scheme.

Option 97. This option uses implicit properties in outflow fluxes in the nearly-implicit scheme.

Option 99. This option adds interfacial heat transfer from the volume above the vertically stratified volume.

2.2 Print Control

The following section describes the input by which the user can specify the contents of the printed output. The printed output is divided into blocks and an individual block may be added or deleted from the printed output. Blocks can be enabled by use of Card 4 or blocks can by disabled by use of Card 5. Either Card 4 or Card 5 but not both input cards may be included in an input deck. If neither card is included in an input deck, all available printout appears on the printed output file. In addition to specifying which blocks appear in the printed output, the volumes and/or junctions for which information is printed within each block can be specified on Cards 2 and 3 respectively. The print control information is not saved for restart. If the print control effect needs to be carried into a restart, these cards will need to be re-entered in the input deck.

2.2.1 Card 2, Volume Print Control

This card is an optional card. If this card is present, the major edits, minor edits, and diagnostic edits contain information for only the volumes listed on this card. Single volume identifiers may be entered as well as pairs of volume identifiers. Pairs of volume identifiers specify a range of volumes to be printed and the second identifier in the pair must be a negative number and must be separated from the first number in the pair by a white space. The volume identifiers in a pair must also be in increasing numerical order. There is no limit to the number of single volume identifiers or pairs of identifiers which may be listed on this card. Heat structures connected to the volumes listed on this card are printed on the major edits and diagnostic edits. If the entire heat structure print block of the major edit is suppressed by the action of either Card 4 or 5, no heat structure information is printed even if the volume to which a particular heat structure is attached is listed on this card. The same is true for the heat structure portion of the diagnostic edit where the heat structure information for heat structures connected to volumes listed on this card is added to the diagnostic edit unless that portion of the diagnostic edit is suppressed by the action of Cards 4 or 5.

W1(I) Volume identifier.

W2(I) Volume identifier.

....

2.2.2 Card 3, Junction Print Control

This card is an optional card. If this card is present, the major edits, minor edits, and diagnostic edits contain information for only the junctions listed on this card. The rules for specifying junctions are the same as for specifying volumes on Card 2.

W1(I) Junction identifier.

W2(I) Junction identifier.

....

2.2.3 Card 4, Enable Printed Output Block

This is an optional card. If this card is present, printed output from the blocks listed on this card are added to the printed output file. All blocks not listed on this card are suppressed. The names of the blocks and a short description of the blocks are contained in **Table 2.2-1**.

W1(A) Name of first block of printout to be enabled.

W2(A) Name of second block of printout to be enabled.

....

2.2.4 Card 5, Disable Printed Output Block

This is an optional card. The action of this card is similar to that of Card 4 except that blocks listed on this card are suppressed rather than being enabled. Blocks not listed on this card are enabled.

W1(A) Name of first block to be disabled.

W2(A) Name of second block to be disabled.

W3(A) Name of third block to be disabled.

....

Table 2.2-1 Names and description of print blocks.

Name	Description of Print Block
ACCUM	Diagnostic edit from subroutine ACCUM
BRNTRN	Diagnostic edit from subroutine BRNTRN
CCFL	Diagnostic edit from subroutine CCFL
CHFCAL	Diagnostic edit from subroutine CHFCAL
CONDEN	Diagnostic edit from subroutine CONDEN
DITTUS	Diagnostic edit from subroutine DITTUS
EQFINL	Diagnostic edit from subroutine EQFINL
FWDRAG	Diagnostic edit from subroutine FWDRAG
HT1TDP	Diagnostic edit from subroutine HT1TDP
HT2TDP	Diagnostic edit from subroutine HT2TDP
HTADV	Diagnostic edit from subroutine HTADV
HTFILM	Diagnostic edit from subroutine HTFILM
HTFINL	Diagnostic edit from subroutine HTFINL
HTRC1	Diagnostic edit from subroutines HTRC1 and QFHTRC
HTRCN2	Diagnostic edit from subroutine HTRCN2
HYDRO	Diagnostic edit from subroutine HYDRO
ICOMPT	Diagnostic edit from subroutine ICOMPT
ISTATE	Diagnostic edit from subroutine ISTATE
JCHOKE	Diagnostic edit from subroutine JCHOKE
JPROP	Diagnostic edit from subroutine JPROP
NONCND	Diagnostic edit from subroutine NONCND

Table 2.2-1 Names and description of print blocks. (Continued)

Name	Description of Print Block
PHANTJ	Diagnostic edit from subroutine PHANTJ
PHANTV	Diagnostic edit from subroutine PHANTV
PIMPLT	Diagnostic edit from subroutine PIMPLT
PINTFC	Diagnostic edit from subroutine PINTFC
PREDNB	Diagnostic edit from subroutine PREDNB
PRESEQ	Diagnostic edit from subroutine PRESEQ
PSTDNB	Diagnostic edit from subroutine PSTDNB
QFMOVE	Diagnostic edit from subroutine QFMOVE
SIMPLT	Diagnostic edit from subroutine SIMPLT
SSTCHK	Diagnostic edit from subroutine SSTCHK
STACC	Diagnostic edit from subroutine STACC
STATE	Diagnostic edit from subroutine STATE
STATEP	Diagnostic edit from subroutine STATEP
SUBOIL	Diagnostic edit from subroutine SUBOIL
SYSITR	Diagnostic edit from subroutine SYSITR
SYSSOL	Diagnostic edit from subroutine SYSSOL
TSTATE	Diagnostic edit from subroutine TSTATE
VALVE	Diagnostic edit from subroutine VALVE
VEXPLT	Diagnostic edit from subroutine VEXPLT
VFINL	Diagnostic edit from subroutine VFINL
VIMPLT	Diagnostic edit from subroutine VIMPLT
VLVELA	Diagnostic edit from subroutine VLVELA
VOLVEL	Diagnostic edit from subroutine VOLVEL
TRIP	Section in major edit describing trips
POWER	Sections in major edit describing reactor power and nodal kinetics data
VOLUME	Section in major edit describing volumes

Table 2.2-1 Names and description of print blocks. (Continued)

Name	Description of Print Block
JUNCTION	Section in major edit describing junctions
HEATSTR	Section in major edit describing heat structures
RADHT	Section in major edit describing radiation heat transfer
REFLOOD	Section in major describing reflood model
CONTROL	Section in major edit describing control system
INPUT	Printout of user input
MIEDIT	Minor edits
ZONETH	Section of major edit describing the thermal hydraulic properties in the zones for nodal kinetics
XSECT	Section of major edit describing the neutron cross sections, flux, power, power density, and relative power density in nodes for nodal kinetics
CNTLRODS	Section of major edit describing the control rod positions for nodal kinetics
NODPRDST	Section of major edit describing the axial and radial power distributions for nodal kinetics
RADNUCLD	Section in major edit describing the output of the radio-nuclide transport model
DETECTR	Section of major edit describing the nuclear detector responces

2.3 Card 100, Problem Type and Option

This card is always required.

W1(A) Problem type. Enter one of the following: NEW, NEWATH, RESTART, PLOT, REEDIT, STRIP, or CMPCOMS.

NEW specifies a new simulation problem. NEWATH must be used for ATHENA problems. ATHENA provides hydrodynamic fluids in addition to light water, heavy water, 1984 light water, and 1995 light water; access to these fluids requires the use of NEWATH in place of NEW. RESTART specifies continuation from some point in a previous problem using information from the RSTPLT file. The PLOT capability is not now functional. PLOT specifies plotting results from a previous simulation run using the

RSTPLT file. REEDIT has not been implemented. STRIP specifies that data are to be extracted (stripped) from the RSTPLT file, and only the data specified are written to the STRIP file. CMPCOMS specifies that a comparison is to be made between dump records on two files written in one or two previous runs.

W2(A) Problem option. This word is needed if W1 is NEW, NEWATH, or RESTART and is optional if W1 is STRIP. If NEW, NEWATH, or RESTART is entered, enter either STDY-ST or TRANSNT to specify the type of simulation. Note the cautions discussed in Section 2.6 when the problem option is changed from STDY-ST to TRANSNT or vice versa. When STRIP is entered in W1, W2 may be optionally entered with BINARY or FMTOUT. BINARY is assumed if W2 is not entered. BINARY indicates an unformatted file. FMTOUT indicates that the same information is to be written as 80-column formatted records. One use of this option is to allow simulation results to be transmitted to a different type of computer. Formats are

STRIP Record 1. (5A8,10X,A8)

STRIP Record 2. (A10,3I10)

STRIP Record 3. (8A10)

STRIP Record 4. (A10,7I10/(8I10))

STRIP Record 5,..., N. (A10, 5X,1P,4E15.6/(5E15.6)).

The STRIP record above refers to the data in one record of the unformatted file. Multiple 80-column formatted records may be written for STRIP Records 3 through N.

2.4 Card 101, Input Check or Run Option

This card is optional for all types.

W1(A) Option. Enter either INP-CHK or RUN; if this card is omitted, RUN is assumed. If INP-CHK is entered, the problem execution stops at the end of input processing; if RUN is entered, the problem is executed if no input errors are detected. This card has no effect on a CMPCOMS problem.

2.5 Card 102, Units Selection

This card is optional for all problem types. If the card is omitted, SI units are assumed for both input and output. If the card is used, enter either SI or BRITISH for each word. SI units used are the basic units, kg, m, s, and the basic combined units such as Pa = kg•m/(s^2•m^2). British units are a mixture of lb_m

(pounds mass), ft, and s, primarily, but pressure is in lb_f/in^2 (lb_f is pounds force), heat energy is in Btu, and power is in MW. Thermal conductivity and heat transfer units use s, not h.

W1(A) Input units.

W2(A) Output units. If this word is missing, SI units are assumed for output.

2.6 Card 103, Restart Input File Control

This card is required for all problem types (W1 of Card 100) except NEW and NEWATH, and it is not allowed for type NEW or NEWATH.

When the problem option (W2 on Card 100) is the same as the problem being restarted, the steady-state or transient is continued, and data on the RSTPLT file up to the point of restart are saved. If the restart continues from the point the previous problem terminated, restart and plot information is added to the end of the previous RSTPLT file. If the restart is prior to the termination point of the previous simulation, restart and plot data after the point of restart are overwritten by new results. A copy should be saved if RSTPLT files from each simulation are needed. If the problem options are different, data up to the point of restart are not saved, problem advancement time is reset to zero, and the RSTPLT file will contain information as if this problem type were NEW.

Some cautions should be observed when the problem advancement time is changed by changing the problem option from STDY-ST to TRANSNT, or vice versa, or the problem advancement time is reset through W1 on Card 200, or the problem advancement time is reset to 0.0 using the reset time flag word on this card (Card 103). Any of these could be specified at restart. When the advancement time is changed, the user is responsible for ensuring that models involving problem time will operate as intended. Affected models include trips using advancement time, control systems using time as an operand (does not include differentiation or integration with respect to time), and table lookup and interpolation using time as the independent variable. If necessary, trips, control systems, general tables, time-dependent volumes, time-dependent junctions, and pump speed tables can all be reentered at restart. With normal modeling practices, little use of modeling features involving advancement time is needed for runs to steady-state and accordingly little effort should be needed in switching from STDY-ST to TRANSNT. Because of the frequent use of time in logic to initiate failures as part of safety systems and in establishing the delay times allowed in most table lookup and interpolation tables, required changes to a transient run may be extensive.

The program does make a change to delay control components when the advancement time is changed. The delay control component operates by maintaining a tabular past history of the delayed functions and using table lookup and interpolation to evaluate the delayed function. The table consists of pairs of time values and the delayed function. When the problem time is changed, the time values in the history table and the time value to store the next point in the table are modified by adding the difference of the new advancement time and the old advancement time. The modified history table is as if the problem being restarted was run with the new advancement time. This may not be the desired change, and, in that case, the user can reenter the delay component.

W1(I) Restart number. This must be a number printed in one of the restart print messages in the output file and whose associated restart information is stored in the RSTPLT file. If -1 is specified, the last restart dump from the RSTPLT file is used. If the problem type (W1 on Card 100) is STRIP, this number must be 0.

or

W1(R) Restart time (s). This can be used with problem type RESTART only (W1 of Card 100). It must be a time that can be calculated from W3 and W7 on Cards 201 through 299 and whose associated restart information is stored in the RSTPLT file. W1 must be within 1.0×10^{-7} s of the restart time in the RSTPLT file. The time for each restart is also printed in one of the restart print messages. If -1.0 is specified, the last restart dump from the RSTPLT file is used.

W2(A) Compress flag. This optional flag indicates whether the restart-plot file was written in a noncompressed or compressed format. If the word is not entered or if NCMPRESS is entered, the restart-plot file is assumed to be in noncompressed format. If CMPRESS is entered, the restart-plot file is assumed to be in compressed format.

W3-12(A) Restart-plot file name. This optional alphanumeric entry can be used to enter the file name of the restart-plot file. Up to eighty characters may be entered as one alphanumeric field. (The code internally treats the field as up to ten eight-character words.) The default file name for the restart-plot file is rstplt. This may be overridden on Unix machines by using the -r option on the command line. Either the default name, the name from the command field, or the name from this field on a previous case may be overridden by this field.

also

W?(A) Reset time flag. If the word RESET is the last word on this card, the problem time is reset to 0.0, This word can be W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, or W13, depending on whether the compress flag (W2) and restart-plot file name (W3-W12) are used.

2.7 Card 104, Restart-Plot File Control

This card can be entered for NEW, RESTART, and STRIP options. For the strip option, this card controls the strip file, and the NONE option is not allowed. If this card is omitted, the restart-plot file is rewound at the end of the problem, but no further action is taken. The user may need to provide system control cards to dispose of the file. To prevent the restart-plot file from being written, a card with NONE must be entered.

W1(A) Action. This word may not be blank. If this word is NONE, no restart-plot file is written. If this word is NCMPRESS, the restart-plot file is written in noncompressed format. If this word is CMPRESS, the file is written in compressed mode. The NCMPRESS and CMPRESS options may be entered only in NEW problems. In RESTART problems, this information is entered on the 103 card.

W2-11(A) Restart-plot file name. This optional alphanumeric entry can be used to enter the file name of the restart-plot file. Up to eighty characters may be entered as one alphanumeric field. (The code internally treats the field as up to ten eight-character words.) The default file name for the restart-plot file is rstplt. This may be overridden on Unix machines by using the -r option on the command line. Either the default name, the name from the command field, or the name from this field on a previous case may be overridden by this field. This information may be entered only in NEW problems. In RESTART problems, this information is entered on the 103 card.

2.8 Card 105, CPU Time Remaining and Diagnostic Edit/Dump

This card is optional. Card 105 controls termination of the transient advancement based on the CPU time remaining for the job; it also controls diagnostic edit and dump file options. Some operating systems allow specification of the CPU time allocated for a job as part of the job control language and also provide a means to determine the CPU time remaining during job execution. As an alternative, Word 3 of this card may be entered as the CPU time allocated. An alternative CPU remaining time is computed by decrementing this quantity by the CPU time used as measured by the program. If Word 3 is omitted or zero, the alternative CPU remaining time is assumed infinite. At the end of each time step, the CPU time remaining for the job is determined from the minimum of the system (if available) and alternative CPU remaining times. If the remaining CPU time is less than Word 1, the transient is immediately terminated. The advancement may not be at the end of a requested time step due to time step reduction; the hydrodynamic, heat conduction, and reactor kinetics may not be advanced to the same point; or the advancement may not be successful and the advancement is scheduled to be repeated with reduced time step. Major edits, minor edits, plot edits, and a restart record are forced. The transient can be restarted from this point as if the problem had not been interrupted. The transient is also terminated after successful advancement over a requested time step and the remaining CPU time is less than Word 2. Word 2 should be larger than Word 1. The default values for Words 1 and 2 are 1.0 and 2.0 seconds. The default values are used if the card is not supplied or the entered numbers are less than default values. Word 2 is also forced to be 1.0 seconds larger than Word 1. The time values must include time for the final minor and major edits (very little time required), plotting, and any other processing that is to follow termination of ATHENA execution. Although this card is optional, we strongly recommend its use with Word 3 nonzero on systems that do not provide a system CPU limit.

Card 105 also controls the diagnostic edit printout through the use of Words 4 and 5. If these words are missing or zero, no diagnostic edit/dump file options are in effect. If Word 4 is greater than zero, then Word 4 is the attempted advancement count number to start a diagnostic edit, and Word 5 is the attempted advancement count number to stop the diagnostic edit as well as the calculation. If Word 4 is -1, a dump file is written on the file specified by the -A option on the command line at the completion of the advancement given in Word 5. Entering 0 in Word 5 writes the dump file just before the start of transient advancement. The problem is terminated after writing the dump file. If Word 4 is -2, a dump file is written on the file given by the -A option after the advancement given in Word 5; the time advancement is then repeated and a dump file following the repeated advancement is written on the file given by the -B option. The problem is terminated after writing the second dump file. Word 5 must be greater than 0 when Word 4 is -2. The default file names are -A dumpfil1 and -B dumpfil2.

W1(R) CPU remaining limit 1 (s).

W2(R) CPU remaining limit 2 (s).

W3(R) CPU time allocated (s).

W4(I) Diagnostic edit/dump file control word as described above.

W5(I) Diagnostic edit/dump file control word as described above.

If the program is compiled with compile time option CTSS defined, entering Word 1 as 0.0 will cause no testing for CPU termination and normal CTSS termination at the end of CPU time can occur. In this case, the problem can be restarted.

2.9 Card 106, R5FORCE File Control

This card can be entered for NEW and RESTART options. If this card is omitted, NONE is assumed for W1.

W1(A) Action. This word may not be blank. If this word is NONE, no R5FORCE file is written. Currently, the use of any other entry for this word will force a R5FORCE file to be written.

W2-11(A) R5FORCE file name. This optional alphanumeric entry can be used to enter the file name of the R5FORCE file. Up to eighty characters may be entered as one alphanumeric field. (The code internally treats the field as up to ten eight-character words.) The default file name for the R5FORCE files is r5-r5f. This may be overwritten on Unix machines by using the -F option on the command line. Either the default name or the name from the command line may be overwritten by this field. This information can be entered on NEW or RESTART problems. For RESTART problems, the R5FORCE data are added to the end of the R5FORCE file.

2.10 Card 107, Steady State Options

This card is optional. The values on this card are used to override the default options for steady state mode. Without this card, trips and CHF are bypassed in steady state mode, the steady state solution is obtained using the nearly-implicit solution algorithm, the mass error time step control is disabled, the steady state checking routine is bypassed, and the heat conduction and hydrodynamic solutions are coupled implicitly and use the same time step size. The values on this card can be used for back compatability with earlier versions of ATHENA.

W1(I) Trip flag. If this word in one, the trip logic is enabled in steady state mode. The default value is zero.

W2(I) CHF flag. If this word is one, CHF is enabled in steady state mode. The default value is zero.

W3(I) Solution controls flag. If this word in one, the solution controls found on the time step cards are used instead of the default values for steady state mode. The default value is zero.

2.11 Card 110, Noncondensable Gas Species

This card is required for all calculations that use noncondensable gas. Nitrogen must be one of the noncondensable gas types specified on this card for any problem having accumulators. This card cannot be entered on a RESTART problem.

W1-WN(A) Noncondensable gas type. Enter any number N of words (maximum 5) of the following noncondensable gas types: ARGON, HELIUM, HYDROGEN, NITROGEN, XENON, KRYPTON, AIR, SF6, OXYGEN, CO2, or CO.

2.12 Cards 115, Noncondensable Mass Fractions

Card 115 is related to Card 110. Card 115 is required if Card 110 is entered unless only one species is entered on Card 110, and then the mass fraction is set to 1.0. The number of words on Card 115 must equal the number of words on Card 110. Th card cannot be entered on a RESTART problem. The sum of the mass fractions must sum to one within a relative error of 1.0×10^{-10}. The mass fractions on the card are defaults values and are used for initial conditions in the hydrodynamic volumes, unless mass fractions are entered in the hydrodynamic component data (except for the accumulator which only has nitrogen).

W1-WN(R) Mass fraction for each noncondensable gas type.

2.13 Card 119, Gravity Constant

This card is optional and specifies the gravitational constant. If not entered, the earth gravitational constant of 9.80665 m/s^2 is used .

W1(R) Gravitational constant (m/s^2, ft/s^2). A positive number, which must be greater than or equal to 1.0×10^{-6} m/s^2 (or $3.280839895 \times 10^{-6}$ ft/s^2 if British input is used), is used as the gravitational constant. If -1.0 is entered, the earth gravitational constant is used.

2.14 Cards 120 through 129, Hydrodynamic System Control

Independent hydrodynamic systems can be described by the hydrodynamic component input. The term independent hydrodynamic systems means that there is no possibility of flow between the independent systems. A typical example would be the primary and secondary systems in a reactor where heat flows from the primary system to the secondary system in the steam generator but there is no fluid connection. If a tube rupture were modeled, the two systems would no longer be independent. Input processing lists an elevation for each volume in each independent hydrodynamic system and includes a check on elevation closure for each loop within a system. A reference volume is established for each system through input or default.

These cards are optional for each system. If not entered for a system, that system contains H_2O as the fluid unless a different fluid is specified in hydrodynamic component data, and the lowest numbered volume in each system is the reference volume. Additionally, the reference volume has a default elevation of zero.

2.14.1 Hydrodynamic System Card

W1(I) Reference volume number of the system. This must be a volume in the hydrodynamic system.

W2(R) Reference elevation of the volume center relative to a fixed z-axis for the system (m, ft).

W3(A) Fluid type for the system. Enter H2O, D2O, H2, LI, K, HE, N2, NA, NAK, LIPB, NH3, H2ON, GLYCEROL, BLOOD, BIPB, H2O95, or CO2.

W4(A) Optional alphanumeric name of system used in output editing. *NONE* is used if this word not entered.

W5(I) System information flag. This word has the packed format g. This word is optional. If this word is not entered, g = 0 is used.

The digit g specifies whether noncondensable gas is present for this system. g = 0 specifies that noncondensable gas is present for this system. g = 1 specifies that noncondensable gas is not present for this system. If g = 1 (no noncondensable) in a system and if the digit t = 4, 5, 6, or 8 in the hydrodynamic volume component control word εbt (see Section 7 of this Appendix A), an input error will result.

2.15 Cards 140 through 147, Self-Initialization Option Control

These cards are optional, are not needed, and are only used as a cross-check on the controllers specified in Section 14. Data supplied on these cards are used to invoke the self-initialization option. These data describe which and how many of each controller will be used. To retain generality and flexibility, the self-initialization option does not require that the steady-state and nearly-implicit solution scheme options be concurrently turned on. However, this is the recommended procedure. These latter options are invoked through input data Cards 100 and 201 through 299. In addition to the data cards described below, the user must furnish data on the controllers to be used, as described in Section 14.

2.15.1 Card 140, Self-Initialization Control

This card specifies the number and type of controllers desired.

W1(I) Number of pump controllers.

W2(I) Number of steam flow controllers.

W3(I) Number of feedwater controllers.

2.15.2 Cards 141 through 142, Self-Initialization Pump Controller and Identification

These cards establish the relationship between the pump number and the number of the pump controller. For each pump so referenced, the user *must* use the time-dependent pump velocity option. For pump component Card CCC6100, Words 2 and 3 must be the alphanumeric and numeric parts for the pump controller. The time-dependent pump velocity data (pump component Cards CCC6100 through CCC6199) should be input so that the search variable and pump velocity are related by a straight line through the origin with a slope of 1.

W1(I) Component number of pump number.

W2(I) Controller identification number for pump number 1.

W3(I) Component number of pump number 2.

W4(I) Controller identification number for pump number 2.

A maximum of six pump/controller pairs may be entered.

2.15.3 Cards 143 through 144, Self-Initialization Steam Flow Controller Identification

These cards establish the relationship between the steam flow control valve number and the steam flow controller number.

W1(I) Component number of steam flow control valve number 1.

W2(I) Controller number of steam flow controller for steam flow control valve number 1.

W3(I) Component number of steam flow control valve number 2.

W4(I) Controller number of steam flow controller for steam flow control valve number 2.

A maximum of six control valve/controller pairs may be entered. Note that in the above the valve component is assumed to be the control component. However, the user is not constrained to use a valve and may use a pump or a time-dependent junction. CAUTION: only a servo valve, a time-dependent junction, or a pump may be used, or a diagnostic error will result.

2.15.4 Cards 145 and 146, Self-Initialization Feedwater Controller Identification

These cards establish the relationship between the feedwater valve number and the feedwater controller number.

W1(I) Component number of feedwater valve number 1.

W2(I) Controller id number of the feedwater controller for feedwater valve number 1.

W3(I) Component number of feedwater valve number 2.

W4(I) Controller id number of the feedwater controller for feedwater valve number 2.

A maximum of six control valve/controller pairs may be entered. Note that in the above it is assumed that a valve component is the control component. However, the user is not constrained to use a valve and may use a pump or time-dependent junction. CAUTION: only a servo valve, time-dependent junction, or a pump is allowed, or a diagnostic will result, such as a time-dependent junction with the controller output used as the independent variable in place of time.

2.15.5 Card 147, Pressure and Volume Control Component Identification

This card identifies the component number, connection data, and pressure level for the time-dependent volume that is to provide pressure and volume control during the self-initialization null transient.

W1(I) Component number of time-dependent volume that replaces the pressurizer.

W2(I) Component number to which the above time-dependent volume is connected; CAUTION: only a single-junction is allowed or an error will result.

W3(R) Desired steady-state pressure.

3 Cards 200 through 299, Time Step Control Cards

3.1 Card 200, Initial Time Value and User-Controlled Time Step

This card is optional. See the description of each word on this card for the default values if this card is not entered.

W1(R) Initial time. If not entered, the simulation time at the start of the advancements is zero for a NEW problem, the advancement time at the point of restart for a RESTART problem, or zero for a RESTART problem in which the problem option switches from STDY-ST to TRANSNT or vice versa. If this card is entered, the simulation time is set to the entered value, which must be greater than or equal to zero. Setting the simulation time with this entry can be done on any NEW or RESTART problem but with most applications should only be used in NEW or RESTART problems that switch from the STDY-ST or TRANSNT options. See the cautions discussed in Section 2.6 of this Appendix A for this capability. When needing to enter W2 but not wishing to enter a new initial time, enter -1.0, which is a flag to ignore this word.

W2(I) Control variable number for user-controlled time step. This word is optional. A nonzero number specifies a control variable whose value is used for user-specified time step control. The time step will be determined from the maximum of the value of the control variable and the current minimum time step entered on Cards 201 through 299. The time step will be equal to or less than this value and depends on the current requested time step, the mass error and other error checks, the Courant limit, and the time-step reduction options.

3.2 Cards 201 through 299, Time Step Control

At least one card of this series is required for NEW problems. If this series is entered for RESTART problems, it replaces the series from the problem being restarted. This series is not used for other problem types. Card numbers need not be consecutive.

W1(R) End time for this set (s). This quantity must increase with increasing card number. On a first run, the end time would normally be greater than the initial time. The end time is allowed to be the same as the initial time. If this is the case, the code will stop at the initial time (also write a major edit to the printed output and restart information to the restart-plot file) if this is the only 201 through 299 card, and the code will continue to the end time of the last 201 through 299 card if there are more then one 201 through 299 card.

On a restart run, the end time would normally be greater than the restart time. The end time is allowed to be the same as the restart time. If this is the case, the code will stop at the restart time (also write a major edit to the printed output and restart information to the restart-plot file) if this is the only 201 through 299 card, and the code will continue to the end time of the last 201 through 299 card if there are more that one 201 through 299 card.

W2(R) Minimum time step (s). This quantity should be a positive number $\leq$ 1.0E-6. If a larger number is entered, it is reset to 1.0E-6.

W3(R) Maximum time step (s). This quantity is also called the requested time step. In transient problems (Word 2 = TRANSNT for Card 100), the user should be careful not to make this too large for the first time step.

W4(I) Control option (see Section 8.2 for a discussion of this input). This word has the packed format ssdtt. It is not necessary to input leading zeros.

The digits ss, that represent a number from 0 through 15, are used to control the printed content of the major edits. The number is treated as a four-bit binary number. If no bits are set (i.e., the number is 0), all the standard major printed output is given. If the first bit from the right is set (i.e., ss = 1 if the other bits are not set), the heat structure temperature block is omitted. If the second bit from the right is set (i.e., ss = 2 if the other bits are not set), the second portion of the junction block is omitted. If the third bit from the right is set (i.e., ss = 4 if the other bits are not set), the third and fourth portions of the volume block are omitted. If the fourth bit from the right is set (i.e., ss = 8 if the other bits are not set), the volume and junction statistics blocks are omitted.

The digit d, which represents a number from 0 through 7, can be used to obtain extra output at every hydrodynamic time step. The number is treated as a three-bit binary number. If no bits are set (i.e., the number is 0), the standard output at the requested frequency using the maximum time step is obtained (see words 5 and 6 of this card). If the number is nonzero, output is obtained at each successful time step; and the bits indicate which output is obtained. If the first bit from the right is set (i.e., d = 1 if the other bits are not set), major edits are obtained every successful time step. If the second bit from the right is set (i.e., d = 2 if the other bits are not set), minor edits are obtained every successful time step. If the third bit from the right is set (i.e., d = 4 if the other bits are not set), plot records are written every successful time step. These options should be used carefully, since considerable output can be generated.

The digits tt, that represent a number from 0 through 63, are used to control the time step. The number is treated as a six-bit binary number. The effect of no bits being set, i.e., 0 being entered, and the effect of each bit are first described followed by the recommended combination of bits.

If no bits are set (i.e., the number is 0), no error estimate time step control is used, and the maximum time step is attempted for both hydrodynamic and heat structure advancement. The hydrodynamic time step, however, is reduced to the material Courant limit and further to the minimum time step for cases such as water property failures. If the first bit from the right is set (i.e., tt = 1 if the other bits are not set), the hydrodynamics advancement, in addition to the time step control when no bits are set, uses a mass error analysis to control the time step between the minimum and maximum time step. If the second bit from the right is set (i.e., tt = 2 if the other bits are not set), the heat conduction/transfer time step is the same as the hydrodynamic time step; if the second bit from the right is not set, the heat conduction/transfer time step uses the maximum time step. If the third bit from the right is set (i.e., tt = 4 if the other bits are not set), the heat conduction/transfer and hydrodynamics are coupled implicitly; if the third bit from the right is not set, the heat conduction/transfer and hydrodynamic advancements are done separately and the information between the models is coupled explicitly. If the fourth bit from the right is set (i.e., tt = 8 if the other bits are not set), the nearly-implicit scheme is used to advance the hydrodynamics; if the fourth bit from the right is not set, the semi-implicit scheme is used to advance the hydrodynamics. If the fifth bit from the right is set (i.e., tt = 16 if the other bits are not set), the steady-state calculation will not be terminated by the steady-state detecting algorithm (however, there will be algorithm messages in the output file); if the fifth bit from the right is not set, the steady-state calculation will be terminated by the algorithm when it detects steady-state has been reached. If the sixth bit from the right is set (i.e., tt = 32 if the other bits are not set), the on-line algorithm selection of time migration is used to advance the hydrodynamics. The semi-implicit scheme will be used when the time step is below the Courant limit, and the nearly-implicit scheme will be used when a large time step can be taken. We do not recommend using this on-line algorithm at this time.

We recommend not using tt equal to 0 except for special testing situations. The use of tt equal to 1 is possible if the maximum time step is kept sufficiently small to ensure that the explicit connection between the heat conduction/transfer and hydrodynamics calculations remains stable. If there is any doubt, use tt equal to or greater than 3 (sets first bit and second bit). Using tt equal to 3 or 11 specifies the semi-implicit or the nearly-implicit advancement scheme, respectively, with both schemes using time step control, the heat conduction and hydrodynamics use the same time step, and the heat conduction/transfer and hydrodynamics are advanced separately. Using tt equal to 7 or 15 specifies the same features as tt equal to 3 or 11 and, in addition, specifies the implicit advancement of the heat conduction/transfer with the hydrodynamics. The nearly-implicit scheme is suitable for a steady-state and/or self-initialization case problem where the time step is limited by the material Courant limit. The nearly-implicit scheme can also be used during slower phases of a transient problem, though we advise the user that the answers may change somewhat from the semi-implicit scheme answers (depending on the time step size). The nearly-implicit advancement scheme is still under validation (assessment); most of the validation (assessment) for the code has been done with the semi-implicit advancement scheme. We did not recommend use of the implicit coupling of the heat conduction/transfer and hydrodynamics in prior versions since the implicit coupling was only partially implemented. With the implicit coupling now complete, we encourage option tt equal to 7 or 15 be used. Users should be cautioned that the implicit coupling is a recent addition to ATHENA and is still under validation (assessment). When using the implicit coupling, the heat conduction/transfer time step must be the same as the hydrodynamic time step (set the second bit from the right, i.e., add 2) . If this bit is not set when implicit coupling is selected, the code will issue a warning message and set the bit. In steady-state calculations, setting the fifth bit from the right (adding 16) for the early part of the run can ensure the calculation runs to a user-specified time; then, setting the fifth bit off can allow the steady-state convergence to test control the termination of the problem. The use of the on-line algorithm selection of time migration (adding 32) is currently not recommended. There are some flaws in the logic which are under investigation.

W5(I) Minor edit and plot frequency. This is the number of maximum (requested) time advances per minor edit to the printed output and write of plot information to the restart-plot file.

W6(I) Major edit frequency. This is the number of maximum (requested) time-advances per major edit to the printed output.

W7(I) Restart frequency. This is the number of maximum (requested) time-advances per write of restart information to the restart-plot file.

4 Cards 301 through 399, Minor Edit Requests

These cards are optional for NEW and RESTART problems, are required for a REEDIT problem, and are not allowed for PLOT and STRIP problems. If these cards are not present, no minor edits are printed. If these cards are present, minor edits are generated, and the order of the printed quantities is given by the card number of the request card. One request is entered per card, and the card numbers need not be consecutive. For RESTART problems, if these cards are entered, all the cards from the previous problem are deleted.

W1(A) Variable code (alphanumeric).

W2(I) Parameter (numeric).

Words 1 and 2 form the variable request code pair. The quantities that can be edited and the input required are listed below. These quantities can be used in plotting requests, in trip specifications, as search variables in tables, and as operands in control statements. Units for the quantities are also given. Quantities compared in variable trips must have the same units (if neither quantity is a control variable), and input to tables specified by variable request codes must have the specified units. The quantities are listed in alphabetical order within each section. Although the variable request codes in the following sections are shown in upper case, they must be entered in lower case in ATHENA input decks.

The underlined quantities without an asterisk in Section 4.1 through Section 4.10 are always written to the restart-plot file (RSTPLT). Underlined quantities followed by an asterisk have only some of the quantities written to the restart-plot file and the text will indicate which quantities are written. The quantities that are not underlined or some of the quantities underlined that are followed with an asterisk are written to the restart-plot file only if requested on a 2080XXXX card as described in Section 4.15.

4.1 General Quantities

The quantities listed below are unique to the whole problem or to a particular system in the whole problem. The parameter required is indicated for each variable code.

Code	Quantity
COUNT	Current attempted advancement count number. The parameter is 0.
<u>CPUTIME</u>	Current CPU time for this problem (s). The parameter is 0.
<u>DT</u>	Current time step (s). The parameter is 0.
<u>DTCRNT</u>	Current Courant time step (s). The parameter is 0.
<u>EMASS</u>	Estimate of mass error in all the systems (kg, lb_m). The parameter is 0.

ERRMAX Current estimate of the truncation mass error fraction for all the systems. The parameter is 0. This is the maximum of the two types of computed mass error (ε_m or ε_{rms}) discussed in Volume I, Section 8.

NULL Specifies null field. Allowed only on trip cards. The parameter is 0.

STDTRN Steady-state/transient flag. The parameter is 0. For steady-state, the value is 0.0. For transient, the value is 1.0.

TESTDA The array testda, of twenty quantities [real testda(20)], has been defined for the convenience of program developers. This entry with a parameter ranging from 1 through 20 selects testda(parameter). The testda array is initially set to zero, and programming must be inserted to set testda values. The usual purpose of this capability is to allow a simple method for debug information to be printed in minor edits or to be plotted.

<u>TIME</u> Time (s). The parameter is 0. This request cannot be used for minor edit requests.

<u>TMASS</u> Total mass of liquid, vapor, and noncondensable gases in all the systems (kg, lb_m). The parameter is 0.

4.2 System Quantities

The quantities listed below are unique to a particular computational system in the user's input model. The parameter is indicated for each quantity.

LEVHGT Height of two-phase level above bottom of level stack (m, ft). The parameter is nss where n is the system number and ss is the level stack index in the system.

LEVVEL Two-phase level velocity (m/s, ft/s). The parameter is nss where n is the system number and ss is the level stack index in the system.

LEVVDA Void fraction above two-phase level (-). The parameter is nss where n is the system number and ss is the level stack index in the system.

LEVVDB Void fraction below two-phase level (-). The parameter is nss where n is the system number and ss is the level stack index in the system.

LEVVNM Volume number of the volume containing the two-phase level. The parameter is nss where n is the system number and ss is the level stack index in the system.

SYSMER Estimate of mass error in system n (kg, lb_m). The parameter is system number n.

SYSTMS Total mass of steam, water, and noncondensable in system n (kg, lb_m). The parameter is system number n.

4.3 Component Quantities

The quantities listed below are unique to certain components; for example, a pump velocity can only be requested for a pump component. The parameter is the component number, i.e., the three-digit number CCC used in the input cards.

Code	Quantity
ACPGTG	Accumulator vapor/gas specific heat, C_p, at vapor/gas temperature (J/kg•K, Btu/lb_m•^oF).
ACPNIT	Accumulator noncondensable specific heat, C_p, at vapor/gas temperature (J/kg•K, Btu/lb_m•^oF).
ACQTANK	Total energy transport to the vapor/gas by heat and mass transfer in the accumulator (W, Btu/s).
ACRHON	Accumulator noncondensable density (kg/m^3, lb_m/ft^3).
ACTTANK	Mean accumulator tank wall metal temperature (K, ^oF).
ACVDM	Vapor/gas volume in the accumulator tank, standpipe, and surge line (m^3, ft^3).
ACVGTG	Accumulator vapor/gas specific heat, C_v, at vapor/gas temperature (J/kg•K, Btu/lb_m•^oF).
ACVLIQ	Liquid volume in the accumulator tank, standipipe, and surge line (m^3, ft^3).
AHFGTF	Accumulator heat of vaporization at liquid temperature (J/kg, Btu/lb_m).
AHFGTG	Accumulator heat of vaporization at vapor/gas temperature (J/kg, Btu/lb_m).
AHFTG	Accumulator liquid specific enthalpy at vapor/gas temperature (J/kg, Btu/lb_m).
AHGTF	Accumulator vapor/gas specific enthalpy at liquid temperature (J/kg, Btu/lb_m).
AVGTG	Accumulator specific volume at vapor/gas temperature (m^3/kg, ft^3/lb_m).
AVISCN	Accumulator noncondensable viscosity (kg/m•s, lb_m/ft•s).
BETAV	Accumulator vapor saturation coefficient of expansion (K^{-1}, $^oF^{-1}$).
CDIM	GE mechanistic dryer critical inlet moisture quality.

CPREFF Thermodynamic efficiency in the compressor component (-).

CPRHEAD Head in the compressor component (Pa, lb_f/in^2).

CPRMT Motor torque in the compressor component (N-m, lb_f-ft^2).

CPRNRT Inertia of the compressor component (kg-m^2, lb_m-ft^2).

CPRTRQ Sum of hydraulic torque and frictional torque in the compressor component (N-m, lb_f-ft^2).

CPRVEL Rotational velocity in the compressor component (rad/s, rev/min).

DIM GE mechanistic dryer inlet moisture quality.

DMGDT Accumulator/time rate of change in dome vapor/gas mass (kg/s, lb_m/s).

GDRY GE mechanistic separator capacity factor.

OMEGA Inertial valve disk angular velocity (rad/s, rev/min).

PMPHEAD Head in the pump component (Pa, lb_f/ in^2).

PMPMT Motor torque in the pump component(N•m, lb_f•ft).

PMPNRT Inertia in the pump component(kg•m ^{2}, lb_m•ft^2).

PMPTRQ Sum of hydraulic torque and frictional torque in the pump component (N•m, lb_f•ft).

PMPVEL Rotational velocity in the pump component (rad/s, rev/min).

PRZLVL Pressurizer liquid level (m, ft).

THETA Inertial valve disk angular position (degrees).

TUREFF Efficiency of the turbine component.

TURPOW Power developed in the turbine component (W, Btu/s).

TURTRQ Torque developed in the turbine component (N•m, lb_f•ft).

TURVEL Rotational velocity of the turbine component (rad/s, rev/min).

VLVAREA Ratio of the current valve physical area to the junction area. The junction area is the fully open valve physical area for the smooth area option and the minimum of the two connecting volumes for the abrupt area change.

VLVSTEM Ratio of the current valve stem position to the fully open valve stem position for the motor and servo valves when the normalized valve stem position option is used. For the motor and servo valves when the normalized valve area option is used and for all the other valves, this is the ratio of the current valve physical area to the fully open valve physical area.

VOLSTEM Normalized volume of computational volume for variable volume model.

XCO GE mechanistic separator liquid carryover quality.

XCU GE mechanistic separator vapor/gas carryunder quality.

XI GE mechanistic separator inlet quality.

4.4 Volume Quantities

For most of the following variable codes, the parameter is the volume number, i.e., the nine-digit number printed in the major edit. The parameter is CCC010000 for a single-volume; CCC010000 for a time-dependent volume; CCCXX0000 for a volume in a pipe, annulus, or pressurizer component ($01 \leq XX \leq 99$); CCC010000 for the volume in a branch, separator, jetmixer, turbine, feedwater heater, or ECC mixer component; CCC010000 for the volume in a pump component; CCC010000 for the volume in an accumulator component. Some of the quantities are associated with the coordinate directions in the volume, and these quantities are computed for each coordinate direction in use. The parameter for the coordinate direction-related quantities is the volume number plus F, where F is described below. The quantities requiring the volume number plus F are so identified.

Every volume has at least one coordinate direction, and some volumes may have up to three orthogonal coordinate directions. Each coordinate has an inlet face and an outlet face. Faces are numbered 1 through 6, where faces 1 and 2 are the inlet and outlet faces associated with coordinate 1 (x or r), respectively, faces 3 and 4 are inlet and outlet faces associated with coordinate 2 (y or θ), and faces 5 and 6 are inlet and outlet faces associated with coordinate 3 (z). All volumes use coordinate 1. The quantity F to be added to the volume number to form the parameter used with coordinate direction related quantities is 0 or the face number. When F is 0 (i.e., just the volume number), 1, or 2, the volume velocity is for coordinate 1. When F is 3 or 4, the volume velocity is for coordinate 2, and when F is 5 or 6, the volume velocity is for coordinate 3. For the underlined quantities followed by an asterisk in the list below, the coordinate-dependent quantities for coordinate 1 are automatically written to the restart-plot records using the parameter with F equal to 0. The other coordinate-dependent quantities can be written to the plot records using the 2080XXXX card series described in Section 4.15. Input checks are made to ensure the parameter specifies a volume coordinate direction that is in use.

Code	Quantity
AVOL	Area of the volume (m^2, ft^2); the parameter is the volume number plus F.
BETAFF	Liquid isobaric coefficient of thermal expansion, β_f, bulk conditions (K^{-1}, $^oF^{-1}$).
BETAGG	Vapor/gas isobaric coefficient of thermal expansion, β_g, bulk conditions (K^{-1}, $^oF^{-1}$).
BORON	Spatial boron density, ρ_b (kg/m^3, lb_m/ft^3). This is the volume liquid fraction (α_f) times the liquid density (ρ_f) times the boron concentration (C_b). Boron concentration is used for hydrodynamic input, and boron spatial density is used for minor edits and plots.
CSUBPF	Liquid specific heat, C_{pf}, bulk conditions ($J/kg\bullet K$, $Btu/lb_m\bullet {}^oF$).
CSUBPG	Vapor/gas specific heat, C_{pg}, bulk conditions ($J/kg\bullet K$, $Btu/lb_m\bullet {}^oF$).
DRFDP	Partial derivative of ρ_f with respect to pressure (s^2/m^2, s^2/ft^2).
DRFDUF	Partial derivative of ρ_f with respect to U_f ($kg\bullet s^2/m^5$, $lb_m\bullet s^2/ft^5$).
DRGDP	Partial derivative of ρ_g with respect to pressure (s^2/m^2, s^2/ft^2).
DRGDUG	Partial derivative of ρ_g with respect to U_g ($kg\bullet s^2/m^5$, $lb_m\bullet s^2/ft^5$).
DRGDXA	Partial derivative of ρ_g with respect to X_n (kg/m^3, lb_m/ft^3).
DTDP	Partial derivative of T^s with respect to pressure (K/Pa, $in^2\bullet {}^oF/lb_f$).
DTDUG	Partial derivative of T^s with respect to U_g ($s^2\bullet K/m^2$, $s^2\bullet {}^oF/ft^2$).
DTDXA	Partial derivative of T^s with respect to X_n (K, ^oF).
DTFDP	Partial derivative of T_f with respect to pressure (K/Pa, $in^2\bullet {}^oF/lb_f$).
DTFDUF	Partial derivative of T_f with respect to U_f ($s^2\bullet K/m^2$, $s^2\bullet {}^oF/ft^2$).
DTGDP	Partial derivative of T_g with respect to pressure (K/Pa, $in^2\bullet {}^oF/lb_f$).
DTGDUG	Partial derivative of T_g with respect to U_g ($s^2\bullet K/m^2$, $s^2\bullet {}^oF/ft^2$).

DTGDXA	Partial derivative of T_g with respect to X_n (K, ^oF).
FLOREG	Flow regime number; the parameter is the volume number. A chart showing the meaning of each number is shown in Section 2 of this volume of the manual.
FWALF	Liquid wall frictional drag coefficient (kg/m^3•s, lb$_m$/ft^3•s); the parameter is the volume number plus F.
FWALG	Vapor/gas wall frictional drag coefficient (kg/m^3•s, lb$_m$/ft^3•s); the parameter is the volume number plus F.
GAMMAC	Mass transfer rate per unit volume at the vapor/liquid interface in the boundary layer near the wall for condensation (kg/m^3•s, lb$_m$/ft^3•s).
GAMMAI	Mass transfer rate per unit volume at the vapor/liquid interface in the bulk fluid for vapor generation/condensation (kg/m^3•s, lb$_m$/ft^3•s).
GAMMAW	Mass transfer rate per unit volume at the vapor/liquid interface in the boundary layer near the wall for vapor generation (kg/m^3•s, lb$_m$/ft^3•s).
HGF	Direct heating heat transfer coefficient per unit volume (W/m^3•K, Btu/s•ft^3•^{o}F).
HIF	Liquid side interfacial heat transfer coefficient per unit volume (W/m^3•K, Btu/s•ft^3•^{o}F).
HIG	Vapor/gas side interfacial heat transfer coefficient per unit volume (W/m^3•K, Btu/s•ft^3•^{o}F).
HSTEAM	Vapor specific enthalpy at bulk conditions using partial pressure of vapor (J/kg, Btu/lb$_m$).
HVMIX	Specific enthalpy of the liquid and vapor/gas (J/kg, Btu/lb$_m$).
KAPPAF	Liquid isothermal compressibility, κ_f, bulk conditions (Pa^{-1}, in^2/lb$_f$).
KAPPAG	Vapor/gas isothermal compressibility, κ_g, bulk conditions (Pa^{-1}, in^2/lb$_f$).
P	Volume pressure (Pa, lb$_f$/in^2).
PECLTV	Peclet number.
PPS	Vapor partial pressure (Pa, lb$_f$/in^2).

Q Total volume heat source from the wall and direct moderator heating to liquid and vapor/gas (W, Btu/s). This variable request is the same as Q.wall.tot. in the major edits.

QUALA Volume noncondensable mass fraction.

QUALAN1 Volume noncondensable mass fraction for the first species identified on Card 110.

QUALAN2 Volume noncondensable mass fraction for the second species identified on Card 110.

QUALAN3 Volume noncondensable mass fraction for the third species identified on Card 110.

QUALAN4 Volume noncondensable mass fraction for the fourth species identified on Card 110.

QUALAN5 Volume noncondensable mass fraction for the fifth species identified on Card 110.

QUALE Volume equilibrium quality used in the wall heat transfer. This quality uses phasic enthalpies and mixture quality, with the mixture enthalpy calculated using the flow quality.

QUALS Volume static quality.

QWG Volume heat source from the wall and direct moderator heating to vapor/gas (W, Btu/s). This variable request is the same as Qwg.wall.gas. in the major edits.

RHO Total density (kg/m^3, lb$_m$/ft^3).

RHOF Liquid density (kg/m^3, lb$_m$/ft^3).

RHOG Vapor/gas density (kg/m^3, lb$_m$/ft^3).

RHOM Total density for the mass error check (kg/m^3, lb$_m$/ft^3).

SATHF Liquid specific enthalpy at saturation conditions using partial pressure of vapor (J/kg, Btu/lb$_m$).

SATHG Vapor specific enthalpy at saturation conditions using partial pressure of vapor (J/kg, Btu/lb$_m$).

SATTEMP Volume saturation temperature based on the partial pressure of vapor (K, ^{o}F).

SIGMA Surface tension (N/m, lb$_f$/ft).

SOUNDE Volume sound speed (m/s, ft/s).

TEMPF Volume liquid temperature (K, ^oF).

TEMPG Volume vapor/gas temperature (K, ^oF).

THCONF Liquid thermal conductivity (W/m•K, Btu/s•ft •^oF).

THCONG Vapor/gas thermal conductivity (W/m•K, Btu/s•ft •^oF).

TIENGV Total internal energy (of both phases and noncondensables) in volume (J, Btu).

TMASSV Total mass (includes both phases and noncondensables) in volume (kg, lb_m).

TSATT Volume saturation temperature based on the total pressure (K, ^oF).

UF Liquid specific internal energy (J/kg, Btu/lb_m).

UG Vapor/gas specific internal energy (J/kg, Btu/lb_m).

VAPGEN Total mass transfer rate per unit volume at the vapor/liquid interface in the bulk fluid for vapor generation/condensation and in the boundary layer near the wall for vapor generation/condensation (kg/m^3•s, lb_m/ft^3•s).

VELF* Volume oriented liquid velocity (m/s, ft/s); the parameter is the volume number plus F.

VELG* Volume oriented vapor/gas velocity (m/s, ft/s); the parameter is the volume number plus F.

VISCF Liquid viscosity (kg/m•s, lb_m/ft•s).

VISCG Vapor/gas viscosity (kg/m•s, lb_m/ft•s).

VOIDF Volume liquid fraction.

VOIDG Volume vapor/gas fraction (void fraction).

VOIDLA Void fraction above the level.

VOIDLB Void fraction below the level.

VOLLEV Location of the level inside the volume (m, ft).

VVOL Volume of the volume (m^3, ft^3).

4.5 Junction Quantities

For the following variable request codes, the parameter is the junction number, i.e., the nine-digit number printed in the major edit. The parameter is CCC000000 for a single-junction; CCC000000 for a time-dependent junction; CCCXX0000 for a junction in a pipe component (01 $\leq$ XX $\leq$ 99); CCCMM0000 for a junction in a branch, separator, jetmixer, turbine, or ECC mixer component (01 < MM $\leq$ 09); CCC000000 for a valve junction; CCC010000 for the inlet junction in a pump component; CCC020000 for the outlet junction in a pump component; CCCIINN00 for a junction in the multiple-junction component (01 $\leq$ II $\leq$ 99, 01 $\leq$ NN $\leq$ 99); CCC010000 for the junction in an accumulator component.

Code	Quantity
C0J	Junction distribution coefficient. The 0 in C0J is the number zero and not the upper case letter O. This is the variable C_0 in Volume I of the manual.
CCFLF	Junction CCFL flag. The value is zero if the flow is not ccfl-limited, and the value is one if the flow is ccfl-limited.
CHOKEF	Junction choking flag. The value is 0 if the flow is not choked, and is 1 if the flow is choked.
DLLPZK	Junction elevation change pressure drop (from side) (Pa, lb_f/in^2).
DLLPZL	Junction elevation change pressure drop (to side) (Pa, lb_f/in^2).
DPELJ	Junction elevation change pressure drop (total) (Pa, lb_f/in^2).
DPFKJ	Junction wall friction and form loss pressure drop (total) (Pa, lb_f/in^2).
FIJ	Interphase friction coefficient ($N{\bullet}s^2/m^5$, $lb_f{\bullet}s^2/ft^5$). This is the variable C_i in Volume I in this manual.
FJUNFT	Total forward user input form loss coefficient for irreversible losses, including Re dependence (dimensionless).
FJUNRT	Total reverse user input form loss coefficient for irreversible losses, including Re dependence (dimensionless).
FLENTH	Total enthalpy flow rate in junction (includes liquid, vapor, and noncondensables) (J/s, Btu/s).
FLENTHA	Noncondensable gas enthalpy flow rate in junction (J/s, Btu/s).

FLENTHF Liquid enthalpy flow rate in junction (J/s, Btu/s).

FLENTHG Vapor/gas enthalpy flow rate in junction (J/s, Btu/s).

FLORGJ Junction flow regime number. A chart showing the meaning of each number is shown in Section 2 of this volume of the manual.

FORMFJ Liquid abrupt area change model form loss factor (dimensionless).

FORMGJ Vapor/gas abrupt area change model form loss factor (dimensionless).

<u>FRICXK</u> Junction wall friction pressure drop (<u>from</u> side) (Pa, lb_f/in^2).

<u>FRICXL</u> Junction wall friction pressure drop (<u>to</u> side) (Pa, lb_f/in^2).

FWALFJ Non-dimensional liquid wall friction coefficient (dimensionless).

FWALGJ Non-dimensional vapor/gas wall friction coefficient (dimensionless).

<u>HLOSSX</u> Junction form loss pressure drop (total) (Pa, lb_f/in^2).

IREGJ Vertical bubbly/slug flow junction flow regime number. A chart showing the meaning of each number is shown in Section 2 of this volume of the manual.

<u>MFLOWFJ</u> Junction liquid mass flow rate (kg/s, lb_m/s).

<u>MFLOWGJ</u> Junction vapor/gas mass flow rate (kg/s, lb_m/s).

<u>MFLOWJ</u> Combined junction liquid and vapor/gas flow rate (kg/s, lb_m/s).

<u>QUALAJ</u> Junction noncondensable mass fraction.

QUALNJ1 Junction noncondensable mass fraction for the first species identified on Card 110.

QUALNJ2 Junction noncondensable mass fraction for the second species identified on Card 110.

QUALNJ3 Junction noncondensable mass fraction for the third species identified on Card 110.

QUALNJ4 Junction noncondensable mass fraction for the fourth species identified on Card 110.

QUALNJ5 Junction noncondensable mass fraction for the fifth species identified on Card 110.

<u>RHOFJ</u> Junction liquid density (kg/m^3, lb_m/ft^3).

RHOGJ Junction vapor/gas density (kg/m^3, lb_m/ft^3).

SONICJ Junction sound speed (m/s, ft/s). When not choked, this is the upstream volume sound speed. When choked, this is the throat sound speed based on the physical junction area; it includes the effect of the density ratio, but does not include the effects of the throat ratio and the discharge coefficients (see Volume IV of the manual).

TASAPK Junction temporal and spatial variation of momentum pressure drop (from side) (Pa, lb_f/in^2).

TASAPL Junction temporal and spatial variation of momentum pressure drop (to side) (Pa, lb_f/in^2).

UFJ Junction liquid specific internal energy (J/kg, Btu/lb_m).

UGJ Junction vapor/gas specific internal energy (J/kg, Btu/lb_m).

VELFJ Junction liquid velocity (m/s, ft/s). This velocity is based on the junction area A_j, which is discussed in Section 2.4 of this volume of the manual.

VELGJ Junction vapor/gas velocity (m/s, ft/s). This velocity is based on the junction area A_j, which is discussed in Section 2.4 of this volume of the manual.

VGJJ Vapor/gas drift velocity (m/s, ft/s). This is the variable v_{gj} in Volume I of the manual.

VOIDFJ Junction liquid fraction.

VOIDGJ Junction vapor/gas fraction (void fraction).

VOIDJ Junction vapor/gas fraction (void fraction) used in the interphase friction.

XEJ Junction quality. When not choked, this is the upstream static quality. When choked, this is the throat quality used in the choking model.

4.6 Heat Structure Quantities

The parameter is the seven-digit heat structure number CCCG0NN with a two-digit number appended except for the request codes HTPOWG, HTVAT, H2GEN, OXTI, and OXTO. For codes other than HTTEMP, HTPOWG, HTVAT, H2GEN, OXTI, and OXTO, the appended number is 00 for the left boundary and 01 for the right boundary. For HTTEMP, the appended number is the mesh point number [i.e., 01 for the first mesh point (left boundary), 02 for the second mesh point, ..., np for the last mesh point (right boundary)]. For HTPOWG, HTVAT, H2GEN, OXTI, and OXTO, omit the two appended digits and use only the seven digit number. Only the left and right surface mesh point temperatures (HTTEMP) are written by default in plot records on the RSTPLT file, and, thus, plot requests in plot-type problems and strip requests are limited to those temperatures unless the interior mesh point temperatures (HTTEMP) are forced to the RSTPLT file through 2080XXXX cards.

Code	Quantity
HTCHF	Critical (maximum) heat flux (W/m^2, Btu/s•ft^2). The parameter is the seven-digit heat structure number, CCCG0NN, with a two-digit number appended (00 for the left boundary and 01 for the right boundary).
HTGAMW	Mass transfer rate per unit volume at the volume vapor/liquid interface in the boundary layer near this boundary (left or right) of the heat structure (wall) for vapor generation /condensation (kg/m^3•s, lb$_m$/ft^3•s). The parameter is the seven-digit heat structure number, CCCG0NN, with a two-digit number appended (00 for the left boundary and 01 for the right boundary).
HTHTC	Heat transfer coefficient (W/m^2•K, Btu/s-ft^2•^{o}F). The parameter is the seven-digit heat structure number, CCCG0NN, with a two-digit number appended (00 for the left boundary and 01 for the right boundary).
HTMODE	Boundary heat transfer mode number (unitless). The mode number indicates which heat transfer regime is currently in effect. The parameter is the seven-digit heat structure number, CCCG0NN, with a two-digit number appended (00 for the left boundary and 01 for the right boundary). This same quantity is valid for the reflood heat structures. A chart showing the meaning of each number is shown in Section 3.2 of this volume of the manual.
HTPOWG	Heat generated within a heat structure (i.e., internal heat source) (W, Btu/s.). The parameter is the seven-digit heat structure number, CCCG0NN.
HTRG	Heat flux to vapor/gas phase (W/m^2, Btu/s•ft^2). The parameter is the seven-digit heat structure number, CCCG0NN, with a two-digit number appended (00 for the left boundary and 01 for the right boundary).
HTRNR	Heat flux (W/m^2, Btu/s•ft^2). The parameter is the seven-digit heat structure number, CCCG0NN, with a two-digit number appended (00 for the left boundary and 01 for the right boundary).
HTTEMP*	Mesh point temperature (K, ^{o}F). The parameter is the seven-digit heat structure number, CCCG0NN, with a two-digit number appended (mesh point number). See the discussion at the beginning of this section (Section 4.6). The left and right surface mesh point temperatures are written to the plot record by default, but interior mesh point temperatures must be requested through the 2080XXXX cards.

<u>HTVAT</u>	Heat structure volume averaged temperature (K, ^{o}F). The parameter is the seven-digit heat structure number, CCCG0NN.
H2GEN	Heat structure hydrogen generated from the metal-water reaction model (kg, lb_m). The parameter is the seven-digit heat structure number, CCCG0NN.
OXTI	Heat structure oxide thickness on the inside of the cladding from the metal-water reaction model (m, ft). The parameter is the seven-digit heat structure number, CCCG0NN.
OXTO	Heat structure oxide thickness on the outside of the cladding from the metal-water reaction model (m, ft). The parameter is the seven-digit heat structure number, CCCG0NN.
PECL	Liquid Peclet number for the heat structure. The parameter is the seven-digit heat structure number, CCCG0NN, with a two-digit number appended (00 for the left boundary and 01 for the right boundary).
STANT	Liquid Stanton number for the heat structure. The parameter is the seven-digit heat structure number, CCCG0NN, with a two-digit number appended (00 for the left boundary and 01 for the right boundary).

4.7 Reflood-Related Quantities

For the following variable codes, the parameter is the heat structure geometry number, i.e., the four-digit number CCCG printed in the major edit.

Code	Quantity
ZQBOT	Elevation of bottom quench front (m, ft). This is the variable WETBOT in Section 4.4 of Volume IV of the manual.
ZQTOP	Elevation of top quench front (m, ft). This is the variable ZTOPQ in Section 4.4 of Volume IV of the manual.
TCHFQF	Temperature at the critical (maximum) heat flux (K, ^{o}F).
TREWET	Rewet, quench, Leidenfrost, or minimum film boiling temperature (K, ^{o}F).
FINES	Current number of axial nodes on a reflood structure.

4.8 Radiation/Conduction Enclosure Quantities

The parameter is the 4-digit number SSNN, where SS is the set number and NN is the surface number.

Code	Quantity

QRAD Radiation/conduction enclosure heat flux for a surface in a set (W/m^2, $Btu/s{\cdot}ft^2$).

4.9 Reactor Kinetics Quantities

The following list is for point kinetics variables. The parameter is zero for the following reactor kinetics quantities except detector responce.

Code	Quantity
RDRES	Nuclear detector response. The parameter is the detector number.
RKACPOW	Total actinide decay power (W).
RKFIPOW	Total immediate (prompt and delayed neutron) fission power (W).
RKGAPOW	Total decay (fission products and actinide) power (W).
RKREAC	Reactivity (dollars).
RKRECPER	Reciprocal reactor period (s^{-1}).
RKTPOW	Total reactor power, i.e., sum of immediate (prompt and delayed neutron) fission power and decay (fission products and actinide) power (W).

CONXE	llnnnn	Xenon concentration in node nnnn on axial level ll (a/cm^3). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL llnnnn nodes to be written to the restart-plot file.
CONI	llnnnn	Iodine concentration in node nnnn on axial level ll (a/cm^3). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL llnnnn nodes to be written to the restart-plot file.
CONSM	llnnnn	Samaruim concentration in node nnnn on axial level ll (a/cm^3). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL llnnnn nodes to be written to the restart-plot file.
CONPM	llnnnn	Promethium concentration in node nnnn on axial level ll (a/cm^3). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL llnnnn nodes to be written to the restart-plot file.

4.10 Control System Quantities

The parameter is the control component number, i.e., the three-digit number, CCC, or the four-digit number, CCCC, used in the input cards.

Code	Quantity
CNTRLVAR	Control component number. These quantities are assumed dimensionless except for a SHAFT component.

4.11 Interactive Variable Quantities

The parameter is 1000000000. The interactive variables are discussed in Section 6 of this Appendix A and can be used in batch or interactive jobs.

Code	Quantity
Variable name	Value of the interactive variable.

4.12 Trip Quantities

The parameter is the trip number, i.e., the three-digit number NNN, or the four-digit number, NNNN, used in the input cards.

Code	Parameter	Quantity
TIMEOF	nnn or nnnn	Time of trip occurring (s). The parameter is the trip number.

4.13 General Table Quantities

The parameter is the general table number, i.e., the three-digit number TTT used in the input cards. If more than one component accesses a general table, the values stored for the general table are from the last access to the general table.

Code	Parameter	Quantity
TABLEIN	ttt	The input argument for the general table.
TABLEOUT	ttt	The general table value for the specified input argument.

4.14 Radionuclide Transport Quantities

These quantities are available if the radionuclide transport model has been activated. The radionuclide specie identifier XXXXX in the variable request code is case sensitive (i.e., may be either upper case, mixed case, or lower case). This is different from all of the other variable request codes that must be entered in lower case.

Code	Parameter	Quantity
XXXXXcon	CCCNN0000	Concentration of radionuclide specie XXXXX in volume NN of component CCC (atoms/m^3). The alphanumeric identifier XXXXX for the specie is Word 1 on Card 220MMM00 for radionuclide MMM.
XXXXXmas	CCCNN0000	Mass of radionuclide specie XXXXX in volume NN of component CCC (kg). The alphanumeric identifier XXXXX for the specie is Word 1 on Card 220MMM00 for radionuclide MMM.
XXXXXact	CCCNN0000	Decay rate of radionuclide specie XXXXX in volume NN of component CCC (disintegrations/sec). The alphanumeric identifier XXXXX for the specie is Word 1 on Card 220MMM00 for radionuclide MMM.
XXXXXeng	CCCNN0000	Energy from decay of radionuclide specie XXXXX in volume NN of component CCC (W). The alphanumeric identifier XXXXX for the specie is Word 1 on Card 220MMM00 for radionuclide MMM.
rtzonphi	GZZZZ	Neutron flux-volume integral in group G of neutron kinetics zone ZZZZ $\left(\frac{n}{m^2 s}\right)$. This variable is only available if the nodal neutron kinetics model is activated.

4.15 Cards 2080XXXX, Expanded Plot Variables

The underlined variables listed above are the default plot variables and are always available for plotting. The variables that are not underlined and some of the underlined variables followed by an asterisk are not written to the restart-plot file by default and are thus unavailable for plotting unless the user enters the desired variables on 2080XXXX cards. The format of these cards is given below. They are only required for the additional variables that the user wants to have written on the restart-plot file. The user can specify that between 1 and 9,999 of these variables be written to the restart-plot file.

The field XXXX need not be consecutive.

W1(A) Variable request code. See the previous sections for valid request codes.

W2(I) Parameter. Enter the parameter associated with the variable request code.

There is as option to enter card 20800000 with Word 1 set to the value of NONE. If only the 20800000 card is entered and there are no 2080XXXX cards (where XXXX takes on a value between 1 and 9,999), only 6 of the default (underlined) variables are written to the restart-plot file and are available for plotting (CPUTIME, DT, DTCRNT, EMASS, TIME, and TMASS). The other default (underlined) variables are not written to the restart-plot file for this case and are not available for plotting. If the 20800000 card is entered and there are some 2080XXXX cards (where XXXX takes on a value between 1 and 9,999), only the 6 default (underlined) variables mentioned above and the variables on the 2080XXXX cards are written to the restart-plot file and are available for plotting.

5 Cards 400 through 799 or 20600000 through 20620000, Trip Input Data

These cards are optional for NEW and RESTART type problems and are not used for other problem types. Two different card series are available for entering trip data, but only one series type may be used in a problem. Card numbers 401 through 799 allow 199 variable trips and 199 logical trips. Card numbers 20600010 through 20620000 allow 1,000 variable trips and 1,000 logical trips.

5.1 Card 400, Trips Cancellation

This card is allowed only for RESTART problems. The card causes all trips in the problem being restarted to be deleted. Any desired trips must be reentered.

W1(A) Discard. Any other entry is an error.

5.2 Card 20600000, Trip Card Series Type

This card, if omitted, selects card numbers 401 through 599 for variable trips and 601 through 799 for logical trips. For this case, the trip numbers are equal to the card numbers.

If this card is entered, card numbers 206NNNN0 are used for entering trip data, and NNNN is the trip number. Trip numbers (NNNN) 1 through 1000 are variable trips, and 1001 through 2000 are logical trips. Trip numbers do not have to be consecutive.

W1(A) Enter EXPANDED. Any other entry is an error.

5.3 Cards 401 through 599 or 20600010 through 20610000, Variable Trips

Each card defines a logical statement or trip condition concerned with the quantities being advanced in time. A trip is false or not set if the trip condition is not met, and true if it is met. On restart, new trips can be introduced, old trips can be deleted, and a new trip with the same number as an old trip replaces the old trip.

The variable codes and parameters are the same as described for minor edits, Section 4. The variable code NULL is allowed for the right side when only a comparison to the constant is desired. The variable code TIMEOF, with the parameter set to the trip number, indicates the time at which the trip was last set. If the trip goes false, TIMEOF is set to -1.0. When a variable trip statement references a TIMEOF variable whose value is -1.0 (i.e., the trip is false), the evaluation of the variable trip is bypassed. Thus, the value of the variable trip remains the same as the value on the previous time step. Quantities compared in variable trips must have the same units if neither quantity is a control variable. Either SI units or British units can be used, depending on Card 102, Word 1. The control variables use the code’s internal units (SI).

W1(A) Variable code. On RESTART problems, this word can also contain DISCARD or RESET. DISCARD deletes the trip; RESET sets the trip to false. If DISCARD or RESET are entered, no further words are entered on the card.

W2(I) Parameter.

W3(A) Relationship. This may be either EQ, NE, GT, GE, LT, or LE, where the symbols have the standard FORTRAN meaning. Do not enter periods as part of the designator. Thus, use EQ rather than .EQ. to specify *equal to*, use NE rather than .NE. to specify *not equal to*, use GT rather than .GT. to specify *greater than*, use GE rather than .GE. to specity *greater than or equal to*, use LT rather than .LT. to specify *less than*, or use LE rather than .LE. to specify *less than or equal to*.

W4(A) Variable code.

W5(I) Parameter.

W6(R) Additive constant.

W7(A) Latch indicator. If L, the trip once set true remains true, even if the condition later is not met. If N, the trip is tested each time advancement.

W8(R) Timeof quantity (s). This word is optional. If it is not entered, the trip is initialized as false and the associated TIMEOF quantity is set to -1.0. If -1.0 is entered, the trip is initialized as false. If zero or a positive number is entered for TIMEOF, the trip is initialized as true. TIMEOF must not be greater than zero for NEW problems and must not be greater than the time of restart for RESTART problems.

The logical statement is “Does the quantity given by Words 1 and 2 have the relationship given by Word 3 with the quantity given by Words 4 and 5 plus Word 6?” If the relationship is false, the trip is false or not set. If the relationship is true, the trip is true or set. The TIMEOF variable is -1.0 if the trip is false. If the trip is true, the TIMEOF variable is the time the trip was last set true. Linear interpolation, along with limits between the current time step and the previous time step, is used to obtain a more accurate time when the trip was last set true. A latched trip is never reset, so the trip time never changes once it changes from -1.0. For the nonlatched trips, the trip time when set remains constant until the trip condition becomes false and then the trip time is -1.0 again. If the trip condition becomes true again, the process is repeated. For trips such as a time test, L should be used to eliminate repeated testing, although no error or difference in results will occur if N is used.

5.4 Cards 601 through 799 or 20610010 through 20620000, Logical

Trips

If these cards are entered, at least one of the variable trip cards must have been entered. Each card defines a logical relationship with the trips defined on these cards or on the variable trip cards. (For a more detailed description of this input, see Section 4.1.4.)

W1(I) Trip number. The absolute value of this number must be one of the trip numbers defined by the variable or logical trip cards. A negative trip number indicates that the complement of the trip is to be used in the test.

W2(A) Operator. The operator may be AND, OR, or XOR. On RESTART problems, this word can also contain DISCARD or RESET. DISCARD deletes the trip; RESET sets the trip to false. If DISCARD or RESET are entered, no further words are entered on the card and Word 1 (W1) may be zero.

W3(I) Trip number. This is similar to Word 1 (W1).

W4(A) Latch indicator. If L, the trip when set remains set. If N, the trip is tested each time advancement.

W5(R) Timeof quantity (s). This word is optional. If not entered, the trip is initialized as false, and the associated TIMEOF quantity is set to -1.0. If -1.0 is entered, the trip is initialized as false. If zero or a positive number is entered for TIMEOF, the trip is initialized as true. TIMEOF must not be greater than zero for NEW problems and must not be greater than the time of restart for RESTART problems.

The trip condition is given by the result of the following logical expression:

CONDITION OF TRIP IN W1 OPERATOR CONDITION OF TRIP IN W3.

5.5 Card 600, Trip Stop Advancement

This card can be entered in NEW and RESTART problems. One or two trip numbers may be entered. If either of the indicated trips are true, the problem advancement is terminated. These trips are tested only at the end of a requested advancement. If the trips can cycle true and false, they should be latched-type trips to ensure being true at the test time.

W1(I) Trip number.

W2(I) Trip number. A second trip number need not be entered.

6 Cards 801 through 1999, Interactive Input Data

An interactive and color display capability exists when the code is interfaced with Nuclear Plant Analyzer (NPA) software. This capability allows a user to view selected results on a color graphics terminal and to modify user-defined input quantities. A user can view ATHENA output in a format that enhances understanding of the transient phenomena and enter commands during the simulation. This input, coupled with trip and control system capability, allows a user to initiate operator-like actions, such as opening/closing valves, starting/stopping/changing speed on pumps, and changing operating power settings.

These data may be entered for either batch or interactive jobs. These cards may be used in a NEW or RESTART job; in a restart job, they add to or replace data in the restarted problem.

These cards define variables that may be changed during execution by data input from a computer terminal if the job is being run interactively. The card input defines input variable names and initial values. These variables are completely independent from the Fortran variable names used in the ATHENA coding, even if they are spelled the same. These user-defined variables can appear wherever variables listed in Section 4 can be used. Thus, the user-defined variables can be used in trips, control variable statements, search arguments for some tables, edited in minor edits, and plotted. With appropriate input, an interactive user can effect changes similar to those made by a reactor operator, such as opening/closing/repositioning valves or setting new operating points in controllers. When entering these user-defined variables, the variable name is the alphanumeric part of the variable request code and 1000000000 is the numeric part.

W1(A) Variable name. Enter the variable name or DELETE in a RESTART job to delete the variable.

W2(R) Initial value. This is not needed if DELETE is entered in Word 1.

In interactive execution, the initial value is used until changed by a terminal entry. The value can be changed at any time and as often as needed. One or more variables can be changed by entering the variable name and value pairs on the computer terminal. An example is VLV1 = 0 VLV2,1 VLV3,0, POWER = 3050.+6, where VLV1, VLV2, VLV3, and POWER are user-defined variable names. The format is identical to data input on cards. An equal sign is treated as a terminating comma. The values should be floating-point quantities, but integers are converted to floating point values. The NPA interface also allows other more convenient methods for entering new values during the simulation.

W3(R) Conversion factor. Word 2 or any terminal-entered replacement value is entered in user-defined units. These quantities should be converted to SI units if they are to be involved in comparisons or computations with quantities advanced in time. User units can be used only if these input interactive variables are used with control variables defined in compatible units. This word, if nonzero, is the conversion factor. If this word is positive, the conversion is V(converted) = V(input)•W3. If negative, V(converted) = V(input)/1.8 - W3. For temperature conversion from ^{o}F to K, Word 3 should be -255.3722222. If this word is missing, the conversion factor defaults to 1.0. If this word is zero, the next two words (W4 and W5) must contain the alphanumeric part and the numeric part of a variable request code. The conversion factor (for the case of Word 3 equal to zero) appropriate for this interactive variable is set to the conversion factor for the variable specified by W4 and W5. If SI units are in use for input, the supplied conversion factor is 1.0. If British units are in use for input, the appropriate conversion factor is set to the conversion factor for the variable specified by W4 and W5.

W4(A) Alphanumeric part of the variable request code. The alphanumeric name CNTRLVAR cannot be used.

W5(A) Numeric part of the variable request code. The numeric part must be omitted if zero.

7 Cards CCCXXNN, Hydrodynamic Components

These cards are required for NEW type problems and may be entered for RESTART problems. Hydrodynamic systems are described in a NEW problem. In a RESTART problem, the hydrodynamic systems may be modified by deleting, adding, or replacing components. The resultant problem must describe at least two volumes and one junction per system, where the junction connects the two volumes. Isolated volumes with no connecting junctions are not allowed. The hydrodynamic card numbers are divided into fields, where CCC is the component number (the component numbers need not be consecutive), XX is the card type, and NN is the card number within type. When a range is indicated, the numbers need not be consecutive.

7.1 Card CCC0000, Component Name and Type

This card is required for each component.

W1(A) Component name. Use a name descriptive of the component's use in system. A limit of 8 characters is allowed for most computers, e.g., workstations, CRAY, and IBM computers.

W2(A) Component type. Enter one of the following component types: SNGLVOL, TMDPVOL, SNGLJUN, TMDPJUN, PIPE, ANNULUS, PRIZER, BRANCH, SEPARATR, FWHTR, JETMIXER, TURBINE, ECCMIX, VALVE, PUMP, MTPLJUN, ACCUM, or the command DELETE. The command DELETE is allowed only in RESTART problems, and the component number must be an existing component at the time of restart. The DELETE command deletes the component.

The remaining cards for each component depend on the type of component.

7.2 Single-Volume Component

A single-volume component is indicated by SNGLVOL for Word 2 on Card CCC0000. The junction connection code determines the placement of the volume within the system. More than one junction may be connected to an inlet or outlet. If an end has no junctions, that end is considered a closed end. Normally, only a branch has more than one junction connected to a volume end. For major edits, minor edits, and plot variables, the volume in the single-volume component is numbered as CCC010000.

7.2.1 Cards CCC0101 through CCC0109, Single-Volume X-Coordinate Volume Data

This card (or cards) is required for a single-volume component. The words can be entered on one or more cards, and the card numbers need not be consecutive.

W1(R) Volume flow area in the x-direction (m^2, ft^2).

W2(R) Length of volume in the x-direction (m, ft).

W3(R) Volume of volume (m^3, ft^3). The program requires that the volume equals the volume flow area times the length (W3 = W1•W2). This is required in all three directions. At least two of the three quantities, W1, W2, and W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the words are zero, the volume must equal the x-direction area times the x-direction length within a relative error of 0.000001. The same relative error check is done for the y- and z-directions.

W4(R) Azimuthal (horizontal) angle (degrees). The absolute value of this angle must be ≤ 360 degrees and is defined as a positional quantity. This angle is in the horizontal x-y plane. The angle 0 degrees is on the x axis, and the angle 90 degrees is on the y axis. Positive angels are rotated from the x axis toward the y axis. This quantity is not used in the calculation but is specified for automated drawing of nodalization diagrams.

W5(R) Inclination (vertical) angle (degrees). The absolute value of this angle must be ≤ 90 degrees. The angle 0 degrees is horizontal; positive angles have an upward inclination, i.e., the inlet is at the lowest elevation. This angle is used in the flow regime determination, in the interphase drag calculation, and for automated drawing of nodalization diagrams. When the absolute value of the inclination (vertical) angle is less than or equal to 30 degrees, the horizontal flow regime map is used. When the absolute value of the inclination (vertical) angle is greater than or equal to 60 degrees, the vertical flow regime map is used. Between 30 and 60 degrees, interpolation is used.

W6(R) Elevation change (m, ft). A positive value is an increase in elevation. The absolute value of this quantity must be less than or equal to the volume length. If the inclination (vertical) angle is zero, this quantity must be zero. If the inclination (vertical) angle is nonzero, this quantity must also be nonzero and have the same sign. The elevation change is used in the gravity head and checking loop closure. See Section 2.4.1 of Volume II of the manual for further discussion.A calculated elevation angle is determined by the arcsin of the ratio of the elevation change (this word) and the volume length (Word 2). This calculated elevation angle is used in the additional stratified force term.

W7(R) Wall roughness in the x-direction (m, ft). The x-direction wall roughness is limited to be greater than or equal to 1.0×10^{-9} times the x-direction hydraulic diameter. If zero, the x-direction wall roughness is computed from 1.0×10^{-9} times the x-direction hydraulic diameter.

W8(R) Hydraulic diameter in the x-direction (m, ft). This should be computed from $4.0 \bullet \frac{\text{x-direction volume flow area}}{\text{x-direction wetted perimeter}}$. If zero, the x-direction hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{x-direction volume flow area}}{\pi}\right)^{0.5}$. A check is made to ensure the x-direction wall roughness is less than half the x-direction hydraulic diameter. See Word 1 for volume flow area.

W9(I) Volume control flags. This word has the packed format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scaler oriented and coordinate direction oriented flags. Only one value for a scaler oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. This word enters the scaler oriented flags and the x-coordinate flag.

The digit t specifies whether the thermal front tracking model is to be used; t = 0 specifies that the front tracking model is not to be used for the volume, and t = 1 specifies that the front tracking model is to be used for the volume. The thermal front tracking model can only be applied to vertically oriented components.

The digit l specifies whether the mixture level tracking model is to be used; l = 0 specifies that the level model not be used for the volume, and l = 1 specifies that the level model be used for the volume. The mixture level tracking model can only be applied to vertically oriented components.

The digit p specifies whether the water packing scheme is to be used; p = 0 specifies that the water packing scheme is to be used for the volume, and p = 1 specifies that the water packing scheme is not to be used for the volume. The water packing scheme is recommended when modeling a pressurizer. The water packing scheme is only applied to vertically oriented volumes.

The digit v specifies whether the vertical stratification model is to be used; v = 0 specifies that the vertical stratification model is to be used for the volume, and v = 1 specifies that the vertical stratification model is not to be used for the volume. The vertical stratification model is recommended when modeling a pressurizer. The vertical stratification model is only applied to vertically oriented volumes.

The digit b specifies the interphase friction that is used; b = 0 specifies that the pipe interphase friction model will be applied, b = 1 specifies that the rod bundle interphase friction model will be applied, and b = 2 specifies that the ORNL ANS narrow channel model will be applied (Card CCC0111 required). The b = 1 option and the b = 2 option are only applied to vertically oriented volumes.

The digit f specifies whether wall friction is to be computed; f = 0 specifies that wall friction effects are to be computed along the x-coordinate of the volume, and f = 1 specifies that wall friction effects are not to be computed along the x-coordinate of the volume.

The digit e specifies if nonequilibrium or equilibrium is to be used; e = 0 specifies that a nonequilibrium (unequal temperature) calculation is to be used, and e = 1 specifies that an equilibrium (equal temperature) calculation is to be used. Equilibrium volumes should not be connected to nonequilibrium volumes. The equilibrium option is provided only for comparison with other codes.

7.2.2 Cards CCC0181 through CCC0189, Single-Volume Y-Coordinate Volume Data

These cards are optional. These cards are used when the user specifies the y-direction connection with the crossflow model. The volume of the volume is the same for the x-, y-, and z-directions. If these cards are entered, either W1 or W2 must be nonzero.

W1(R) Area of the volume in the y-direction (m^2, ft^2). If these cards are missing or if this word is zero, this y-direction volume flow area is computed from $\frac{\text{volume of volume}}{\text{y-direction length}}$.

W2(R) Length of the crossflow volume in the y-direction (m, ft). If these cards are missing, this y-direction length is computed from $2.0 \bullet \left(\frac{\text{x–direction volume flow area}}{\pi}\right)^{0.5}$. If this word is zero, this y-direction length is computed from $\frac{\text{volume of volume}}{\text{y-direction volume flow area}}$.

W3(R) Wall roughness in the y-direction (m, ft). The y-direction wall roughness is limited to be greater than or equal to 1.0×10^{-9} times the y-direction hydraulic diameter. If zero, the y-direction wall roughness is computed from 1.0×10^{-9} times the y-direction hydraulic diameter.

W4(R) Hydraulic diameter in the y-direction (m, ft). If these cards are missing or if this word is zero, this y-direction hydraulic diameter is computed from $4.0 \bullet \left(\frac{\text{y – direction volume flow area}}{\pi \bullet \text{x – direction volume flow area}}\right)^{0.5}$. See Section 2.4 of this volume of the manual. A check is made to ensure the y-direction wall roughness is less than half the y-direction hydraulic diameter.

W5(I) Volume control flags. This word has the general packed format tlpvbfe, but this word is limited to 00000f0 since it only enters the coordinate oriented flags for the y-direction.

The digit f specifies whether wall friction is to be computed; f = 0 specifies that wall friction effects are to be computed along the y-coordinate direction of the volume, and f = 1 specifies that wall friction effects are not to be computed along the y-coordinate direction of the volume.

W6(R)

W7(R)

W8(R) This word is the position change in the fixed z (vertical) direction as flow passes from the y inlet face to the y outlet face (m, ft). This quantity affects problems if connections are made to the y faces.

7.2.3 Cards CCC0191 through CCC0199, Single-Volume Z-Coordinate Volume Data

These cards are optional. These cards are used when the user specifies the z-direction connection with the crossflow model. The volume of the volume is the same for the x-, y-, and z-directions. If these cards are entered, either W1 or W2 must be nonzero.

W1(R) Area of the volume in the z-direction (m^2, ft^2). If these cards are missing or if this word is zero, this z-direction volume flow area is computed from $\frac{\text{volume of volume}}{\text{z-direction length}}$.

W2(R) Length of the crossflow volume in the z-direction (m, ft). If these cards are missing, this z-direction length is computed from $2.0 \bullet \left(\frac{\text{volume flow area}}{\pi}\right)^{0.5}$. If this word is zero, this z-direction length is computed from $\frac{\text{volume of volume}}{\text{z-direction volume flow area}}$.

W3(R) Wall roughness in the z-direction (m, ft). The z-direction wall roughness is limited to be greater than or equal to 1.0×10^{-9} times the z-direction hydraulic diameter. If zero, the z-direction wall roughness is computed from 1.0×10^{-9} times the z-direction hydraulic diameter.

W4(R) Hydraulic diameter in the z-direction (m, ft). If these cards are missing or if this word is zero, this z-direction hydraulic diameter is computed from $4.0 \bullet \left(\frac{\text{z-direction volume flow area}}{\pi \bullet \text{x - direction volume flow area}}\right)^{0.5}$. See Section 2.4 of this volume of the manual. A check is made to ensure the z-direction wall roughness is less than half the z-direction hydraulic diameter.

W5(I) Volume control flags. This word has the general packed format tlpvbfe, but this word is limited to 00000f0 since it only enters the coordinate oriented flags for the z-direction.

The digit f specifies whether wall friction is to be computed; f = 0 specifies that wall friction effects are to be computed along the z-coordinate direction of the volume, and f = 1 specifies that wall friction effects are not to be computed along the z-coordinate direction of the volume.

W6(R)

W7(R)

W8(R) This word is the position change in the fixed z (vertical) direction as flow passes from the z inlet face to the z outlet face (m, ft). This quantity affects problems if connections are made to the z faces.

7.2.4 Card CCC0111, Single-Volume ORNL ANS Interphase Model Pitch and Span Values

This card is required if the interphase friction flag b in Word 9 of Card CCC0101 through CCC0109 is set to 2 (ORNL ANS narrow channel model).

W1(R) Pitch (gap, channel width perpendicular to flow), short dimension (m, ft).

W2(R) Span (channel length perpendicular to flow), long dimension (m, ft).

7.2.5 Card CCC0131, Single-Volume Additional Wall Friction

This card is optional. If this card is not entered, the default values are 1.0 for the laminar shape factor and 0.0 for the viscosity ratio exponent. Two, four, or six quantities may be entered on the card, and the data not entered are set to default values. A description of this input is presented in Section 3 of Volume I.

W1(R) Shape factor for coordinate direction 1.

W2(R) Viscosity ratio exponent for coordinate direction 1.

W3(R) Shape factor for coordinate direction 2.

W4(R) Viscosity ratio exponent for coordinate direction 2.

W5(R) Shape factor for coordinate direction 3.

W6(R) Viscosity ratio exponent for coordinate direction 3.

7.2.6 Cards CCC0141, Single-Volume Alternate Turbulent Wall Friction

This card is optional. This card allows the specification of a user defined turbulent friction factor for each coordinate direction. The turbulent friction factor has the form $f = A + B(Re)^{-C}$, where A, B, and C are entered for each coordinate of each volume. If this card is not entered, the standard turbulent friction factor is used for all coordinates. If the card is entered, the standard turbulent friction factor can be selected for a particular coordinate direction by entering zeros for the three quantities. Three, six, or nine quantities may be entered on the card, and the data not entered are set to zeros.

W1(R) A for coordinate direction 1.

W2(R) B for coordinate direction 1.

W3(R) C for coordinate direction 1.

W4(R) A for coordinate direction 2.

W5(R) B for coordinate direction 2.

W6(R) C for coordinate direction 2.

W7(R) A for coordinate direction 3.

W8(R) B for coordinate direction 3.

W9(R) C for coordinate direction 3.

7.2.7 Card CCC0200, Single-Volume Initial Conditions

This card is required for a single-volume.

W1(I) Control word. This word has the packed format εbt. It is not necessary to input leading zeros.

The digit ε specifies the fluid, where ε =0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120 - 129 Cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O, etc.). The default fluid is that set for the hydrodynamic system by Cards 120 through 129 or this control word in another volume in this hydrodynamic system. The fluid type set on Cards 120 through 129 or these control words must be consistent (i.e., not specify different fluids). If Cards 120 through 129 are not entered and all control words use the default ε = 0, then H_2O is assumed as the fluid.

The digit b specifies whether boron is present or not. The digit b = 0 specifies that the volume liquid does not contain boron; b = 1 specifies that a boron concentration in mass of boron per mass of liquid (which may be zero) is being entered after the other required thermodynamic information.

The digit t specifies how the following words are to be used to determine the initial thermodynamic state. Entering t = 0 through 3 specifies only one component (vapor/liquid). Entering t = 4, 5, 6, or 8 allows the specification of two components (vapor/liquid and noncondensable gas).

With options t equal to 4, 5, 6, or 8, the names of the components of the noncondensable gas must be entered on Card 110, and the mass fractions of the components of the noncondensable gas are entered on Card 115. Card CCC0301 may also be used for the mass fractions of the components of the noncondensable gas.

If t = 0, the next four words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor/gas specific internal energy (J/kg, Btu/lb_m), and vapor/gas void fraction. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the specific internal energies used to define the thermodynamic state. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for the thermodynamic conditions.

If t = 1, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for the thermodynamic conditions.

If t = 2, the next two words are interpreted as pressure (Pa, lb_f/in^2) and static quality in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for the thermodynamic conditions.

If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in nonequilibrium or equilibrium conditions depending on the pressure and temperature used to define the thermodynamic state. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for the thermodynamic conditions.

The following options are used for input of noncondensable states. In all cases, the criteria used for determining the range of values for static quality are;

1. 1.0E-9 $\leq$ static quality $\leq$ 0.99999999, two phase conditions

2. static quality < 1.0 E-9 or static quality > 0.99999999, single-phase conditions.

The static quality is given by $M_g/(M_g + M_f)$, where $M_g = M_s + M_n$. Section 3.2 of Volume I of the manual discusses this further.

Noncondensable options are as follows:

If t = 4, the next three words are interpreted as pressure (Pa, lb_f/in^2), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static quality > 0.0

and $\leq$ 1.0, saturated noncondensables (100% relative humidity) will result. The temperature is restricted to be less than the saturation temperature at the input pressure and less than the critical temperature; otherwise an input error will occur. Setting static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable, 0% relative humidity) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for the thermodynamic conditions.

If $\underline{t}$ = 5, the next three words are interpreted as temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. Both the static and noncondensable qualities are restricted to be between 1.0 E-9 and 0.99999999. Little experience has been obtained using this option, and it has not been checked out. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for the thermodynamic conditions.

If $\underline{t}$ = 6, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor/gas specific internal energy (J/kg, Btu/lb_m), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the specific internal energies used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing ($\underline{t}$ = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume temperature is calculated from the noncondensable energy equation using the input vapor/gas specific internal energy. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for the thermodynamic conditions.

If $\underline{t}$ = 8, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid temperature (K, ^oF), vapor/gas temperature (K, ^oF), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the temperatures used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume specific internal energy is calculated from the noncondensable energy equation using the input vapor/gas temperature. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for the thermodynamic conditions.

W2-W7(R) Quantities as described under Word 1 (W1). Depending on the control word, two through five thermodynamic quantities may be required. Enter only the minimum number required. If entered, boron concentration (mass of boron per mass liquid) follows the last required word for thermodynamic conditions.

7.2.8 Card CCC0300, Single-Volume Variable Volume Control

This card is optional. The presence of this card in the input deck signals that the variable volume option is to be activated for this single-volume component. The items on the card specify how the computational volume of this single-volume component is to be determined. The volume specified on the CCC0101 card for this volume is the maximum value of the computational volume.

W1(I) Control variable number. The value of the indicated control variable is used as either the normalized volume of the computational volume (if Word 2 is not entered on this card) or as the normalized stem position (if Word 2 is entered on this card). This word must be entered as zero if no control variable is to be used.

W2(I) General table number. The input argument for the table is either the value (normalized stem position) of the control variable (entered as Word 1) or time (if Word 1 is entered as zero). If the input argument comes from a control variable, no trip should be specified in the input for the general table.

7.2.9 Card CCC0301 Single Volume Noncondensable Mass Fraction

Ths card is optional. If omitted, the noncondensable mass fractions are obtained from the noncondensable mass fractions entered on Card 115.

W1-WN(R) Mass fractions for the noncondensable species entered on Card 110. The number of words on this card should be the same as on Card 110. The sum of the noncondensable mass fractions must sum to one within a relative error of $1.0\text{x}10^{-10}$.

7.3 Time-Dependent Volume Component

This component is indicated by TMDPVOL for Word 2 on Card CCC0000. For major edits, minor edits, and plot variables, the volume in the time-dependent volume component is numbered as CCC010000.

7.3.1 Cards CCC0101 through CCC0109, Time-Dependent Volume Geometry

This card (or cards) is required for a time-dependent volume component. The nine words can be entered on one or more cards, and the card numbers need not be consecutive.

W1(R) Volume flow area (m^2, ft^2). When a time-dependent volume is used to model a pressure boundary condition (i.e., the time-dependent volume is connected to the system through a normal junction), it is generally recommended that the cross-sectional area of the time-dependent volume be large compared to the area of the normal junction.

W2(R) Length of volume (m, ft). After initialization, the length is set to zero.

W3(R) Volume of volume (m^3, ft^3). The program requires that the volume equals the volume flow area times the length (W3 = W1•W2). At least two of the three quantities, W1, W2, and W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the words are zero, the volume must equal the area times the length within a relative error of 0.000001. After initialization, the volume is set to zero.

W4(R) Azimuthal (horizontal) angle (degrees). The absolute value of this angle must be ≤ 360 degrees. This angle is in the horizontal x-y plane. The angle 0 degrees is on the x axis, and the angle 90 degrees is on the y axis. Positive angles are rotated from the x axis toward the y axis. This quantity is not used in the calculation but is specified for automated drawing of nodalization diagrams.

W5(R) Inclination (vertical) angle (degrees). The absolute value of this angle must be ≤ 90 degrees. The angle 0 degrees is horizontal; positive angles have an upward inclination, i.e., the inlet is at the lowest elevation. This angle is used in the flow regime determination, in the interphase drag calculation, and for automated drawing of nodalization diagrams. As with the other components, this angle determines if the horizontal or vertical flow regime map is used. This is not important for this component, since the correlations that depend on the flow regime maps are not needed for this component. The volume conditions are prescribed through input Cards CCC0201 through CCC0299.

W6(R) Elevation change (m, ft). A positive value is an increase in elevation. The absolute value of this quantity must be less than or equal to the volume length. If the vertical angle is zero, this quantity must be zero. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign. See Section 2.4.1 of Volume II of the manual for further discussion. After initialization, the elevation change is set to zero.

W7(R) Wall roughness (m, ft). The wall roughness is limited to be greater than or equal to $1.0x10^{-9}$ times the hydraulic diameter. If zero, the wall roughness is computed from $1.0x10^{-9}$ times the hydraulic diameter.

W8(R) Hydraulic diameter (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{volume flow area}}{\text{wetted perimeter}}\right)$. If zero, the hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{volume flow area}}{\pi}\right)^{0.5}$. A check is made to ensure the pipe roughness is less than half the hydraulic diameter. See Word 1 for the volume flow area.

W9(I) Volume control flags. This word has the packed format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scaler oriented and coordinate direction oriented flags. Only one value for a scaler oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. This word enters the scaler oriented flags and the x-coordinate flag. The y- and z-coordinate data (wall friction flag f) are not read in for the time-dependent component because the wall friction is not used for time-dependent volumes.

The digit t is not used and must be entered as zero (t = 0). The thermal stratification model is not used in a time-dependent volume.

The digit l is not used and must be entered as zero (l = 0). The level tracking model is not used in a time-dependent volume.

The digit p is not used and should be input as zero (p = 0). The major edit will show p = 1.

This digit v is not used and should be input as zero (v = 0). The major edit will show v = 1.

The digit b specifies the interphase friction that is used; b = 0 specifies that the pipe interphase friction model will be applied, and b=1 specifies that the rod bundle interphase friction model will be applied. The interphase friction models are not used for time-dependent volumes, so either b = 0 or b = 1 can be inputted and the output will show the digit entered.

The digit f specifies whether wall friction is to be computed; f = 0 specifies that wall friction effects are to be computed for the volume, and f = 1 specifies that wall friction effects are not to be computed for the volume. The wall friction model is not used for time-dependent volumes, so either f = 0 or f = 1 can be inputted and the output will show the digit entered.

The digit e specifies if nonequilibrium or equilibrium is to be used; e = 0 specifies that a nonequilibrium (unequal temperature calculation is to be used, and e = 1 specifies that an equilibrium (equal temperature) calculation is to be used. Equilibrium volumes should not be connected to nonequilibrium volumes. The equilibrium option is provided only for comparison to other codes. The nonequilibrium and equilibrium options are not used for time-dependent volumes, so either e = 0 or e = 1 can be used.

7.3.2 Card CCC0200, Time-Dependent Volume Data Control Word

This card is required for a time-dependent volume.

W1(I) Control word for time-dependent data on CCC02NN cards. This word has the packed format εbt. It is not necessary to input leading zeros.

The digit ε specifies the fluid, where ε = 0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120 - 129 cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O, etc.). The default fluid is that set for the hydrodynamic system by Cards 120 through 129 or this control word in another volume in this hydrodynamic system. The fluid type set on Cards 120 through 129 or these control words within the hydrodynamic system must be consistent (i.e., not specify different fluids). If Cards 120 through 129 are not entered and all control words use the default ε = 0, then H_2O is assumed as the fluid.

The digit b specifies whether boron is present or not. The digit b = 0 specifies that the volume liquid does not contain boron; b = 1 specifies that a boron concentration in mass of boron per mass of liquid (which may be zero) is being entered after the other required thermodynamic information.

The digit t specifies how the words of the time-dependent volume data in Cards CCC0201 through CCC0299 are to be used to determine the initial thermodynamic state. Entering t equal to 0 through 3 specifies one component (vapor/liquid). Entering t equal to 4, 5, 6, or 8 allows the specification of two components (vapor/liquid and noncondensable gas).

With options t equal to 4, 5, 6, or 8, the names of the components of the noncondensable gas must be entered on Card 110, and the mass fractions of the components are entered on Card 115.

If t = 0, the second, third, fourth, and fifth words of the time-dependent volume data on Cards CCC0201 through CCC0299 are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor/gas specific internal energy (J/kg, Btu/lb_m), and vapor/gas void fraction. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the specific internal energies used to define the thermodynamic state. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 1, the second and third words of the time-dependent volume data on Cards CCC0201 through CCC0299 are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 2, the second and third words of the time-dependent volume data on Cards CCC0201 through CCC0299 are interpreted as pressure (Pa, lb_f/in^2) and static quality in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 3, the second and third words of the time-dependent volume data on Cards CCC0201 through CCC0299 are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in nonequilibrium or equilibrium conditions depending on the pressure and temperature used to define the thermodynamic state. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

The following options are used for input of noncondensable states. In all cases, the criteria used for determining the range of values for static quality are;

1. 1.0E-9 $\leq$ static quality $\leq$ 0.99999999, two-phase conditions

2. static quality < 1.0E-9 or static quality > 0.99999999, single-phase conditions.

The static quality is given by $M_g/(M_g + M_f)$, where $M_g = M_n + M_s$. Section 3.2 of Volume I of the manual discusses this further.

Noncondensable options are as follows:

If t = 4, the second, third, and fourth words of the time-dependent data on Cards CCC0201 through CCC0299 are interpreted as pressure (Pa, $lb_f/in.^2$), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static quality > 0.0 and $\leq$ 1.0, saturated noncondensables (100% relative humidity) will result. The temperature is restricted to be less than the saturation temperature at the input pressure and less than the critical temperature; otherwise an input error will occur. Setting static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable, 0% relative humidity) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 5, the second, third, and fourth words of the time-dependent data on Cards CCC0201 through CCC0299 are interpreted as temperature (K, ^{o}F), static quality, and noncondensable quality in equilibrium condition. Both the static and noncondensable qualities are restricted to be between 1.0E-9 and 0.99999999. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions. Little experience has been obtained using this option, and it has not been checked out.

If t = 6, the second, third, fourth, fifth, and sixth words of the time-dependent data on Cards CCC0201 through CCC0299 are interpreted as pressure (Pa, $lb_f/in.^2$), liquid specific internal energy (J/kg, Btu/lb_m), vapor/gas specific internal energy (J/kg, Btu/lb_m), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the specific internal energies used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present, and the input processing branches to that type of processing (t = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume temperature is calculated from the noncondensable energy equation using the input vapor/gas specific internal energy. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 8, the second, third, fourth, fifth, and sixth words of the time-dependent data on Cards CCC0201 through CCC0299 are interpreted as pressure (Pa, lb_f/in^2), liquid temperature (K, ^{o}F), vapor/gas temperature (K, ^{o}F), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the temperatures used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present, and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume specific internal energy is calculated from the noncondensable energy equation using the input vapor/gas temperature. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

W2(I) Table trip number. This word is optional. If missing or zero and Word 3 is missing, no trip is used, and the time argument is the advancement time. If nonzero and Word 3 is missing, this number is the trip number, and the time argument is -1.0×10^{308} if the trip is false, and the advancement time minus the trip time if the trip is true.

W3(A) Alphanumeric part of variable request code. This quantity is optional. If not present, time is the search argument. If present, this word and the next are a variable request code that specifies the search argument for the table lookup and interpolation. If the trip number is zero, the specified argument is used. If the trip number is nonzero, -1.0×10^{308} is used if the trip is false, and the specified argument is used if the trip is true. TIME can be selected, but note that the trip logic is different than if this word were omitted. The variable MFLOWJ should not be used as a search variable; a user-initialized control variable that uses MFLOWJ should be used instead (see Volume V).

W4(I) Numeric part of variable request code. This is assumed zero if missing.

7.3.3 Cards CCC0201 through CCC0299, Time-Dependent Volume Data

These cards are required for time-dependent volume components. A set of data consists of the search variable (e.g., time) followed by the required data indicated by control Word 1 on Card CCC0200. The card numbers need not be consecutive, but the value of the search variable in a succeeding set must be equal to or greater than the value in the previous set. One or more sets of data, up to 5,000 sets, may be entered. Enter only the minimum number of words required. If entered, boron concentration follows the last required word for thermodynamic conditions. Linear interpolation is used if the search argument lies between the search variable entries. End-point values are used if the argument lies outside the table values. Only one set is needed if constant values are desired, and computer time is reduced when only one set is entered. Step changes can be accommodated by entering the two adjacent sets with the same search variable values or an extremely small difference between them. Given two identical argument values, the set selected will be the closest to the previous argument value. Sets may be entered one or more per card and may be split across cards. The total number of words must be a multiple of the set size. For large sets of data, continuation cards will be needed. The total number of words on a card and its continuation cards may not exceed 2,047.

Inputting time-dependent volume tables where the search variable is a thermodynamic variable from some other component can run into difficulties if the component numbering is such that the time-dependent volume is initialized before the component providing the needed search variable. This problem can be circumvented by always referencing lower-number components in the search variable. Another reliable fix for this is to make the search variable a control system output in the desired units, while the thermodynamic variable is the control system input in code internal (SI) units. The control system initial value can be set to the desired initial value of the search variable, and this will be used by the time-dependent table.

W1(R) Search variable (e.g., time).

As described above, sets may be entered one or more per card.

7.3.4 Card CCC0301, Time-Dependent Volume Noncondensable Mass Fraction

This card is optional. If omitted, the noncondensable mass fractions are obtained from the noncondensable mass fractions entered on Card 115.

W1-WN(R) Mass fractions for the noncondensable species entered on Card 110. The number of words on this card should be the same as on Card 110. The sum of the noncondensable mass fractions must sum to within a relative error of 1.0×10^{-10}.

7.4 Single-Junction Component

A single-junction component is indicated by SNGLJUN for Word 2 on Card CCC0000. For major edits, minor edits, and plot variables, the junction in the single-junction component is numbered CCC000000.

7.4.1 Cards CCC0101 through CCC0109, Single-Junction Geometry

This card (or cards) is required for single-junction components.

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. An old or an expanded format can be used to connect volumes. In the old format (only allowed for connection to 1-D components), use CCC000000 if the connection is to the inlet side of the component and use CCC010000 if the connection is to the outlet side of the component. In the expanded format, the connection code for 1-D components is CCCXX000F [where CCC is the component number, XX is the volume number (greater than 00 and less than 100) for 1-D pipes/annuli/pressurizers, XX is 01 for all other 1-D components, and F indicates the face number]. A nonzero F specifies the expanded format. The number F equal to 1 and 2 specifies the inlet and outlet faces for the first coordinate direction (x or r), which is a 1-D volume's coordinate direction (x) (see Section 2.1 of VOlume II of this manual). The number F equal to 3 through 6 specifies crossflow (y or z) for 1-D volumes. The number F equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction (y or θ); F equal to 5 and 6 would do the same for the third coordinate direction (z). For connecting to a time-dependent volume using the old format, both CCC000000 and CCC010000 are allowed. For connecting to a time-dependent volume using the expanded format, only the number F equal to 1 or 2 is allowed. Section 4.4 in this Appendix discusses this further.

W2(I) To connection code to a component. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.

W3(R) Junction area (m^2, ft^2). If zero, the area is set to the minimum volume flow area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or smaller than the minimum of the adjoining volume areas. For smooth area changes, there are no restrictions.

W4(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or zero. Note: a variable loss coefficient may be specified (see Section 7.4.3 in this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W5(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. Note: a variable loss coefficient may be specified (see Section 7.4.3 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W6(I) Junction control flags. This word has the packed format jefvcahs. It is not necessary to input leading zeros.

The digit j specifies that this junction is a jet junction; j = 0 specifies that the jet junction model will not be applied, and j = 1 specifies that the jet junction model will be applied. Pool surface condensation is enhanced in the volume above the junction when this model is activated. This junction must be underneath the to volume.

The digit e specifies the modified PV term in the energy equations; e = 0 specifies that the modified PV term will not be applied, and e = 1 specifies that the modified PV term will be applied.

The digit f specifies CCFL options; f = 0 specifies that the CCFL model will not be applied, and f = 1 specifies that the CCFL model will be applied.

The digit v specifies stratification entrainment/pullthrough options, where this model is for junctions connected to a horizontal or vertical volume; v = 0 specifies the model is not applied, v = 1 specifies an upward-oriented junction from a horizontal volume (offtake volume must be vertical), v = 2 specifies a downward-oriented junction from a horizontal volume (offtake volume must be vertical), and v = 3 specifies a centrally (side) located junction from a horizontal or vertical volume. For v = 1 or 2, the horizontal volume flow area must be greater than or equal to the offtake volume flow area.

The digit c specifies choking options; c = 0 specifies that the choking model will be applied, and c = 1 specifies that the choking model will not be applied.

The digit a specifies area change options; a = 0 specifies either a smooth area change or no area change, a = 1 specifies full abrupt area change model (code-calculated K_{loss}, area apportioning at a branch, restricted junction area, and extra interphase drag), and a = 2 specifies a partial abrupt area change model (no code-calculated K_{loss}, but includes area apportioning at a branch, restricted junction area, and extra interphase drag). It is recommended that the abrupt area change model (a = 1 or a = 2) be used at branches.

The digit h specifies nonhomogeneous or homogeneous; h = 0 specifies the nonhomogeneous (two velocity momentum equations) option, and h = 1 or 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 1 or 2), the major edit printout will show a 1.

The digit s specifies momentum flux options; s = 0 specifies momentum flux in both the to volume and the from volume, s = 1 specifies momentum flux in the from volume but not in the to volume, s = 2 specifies momentum flux in the to volume but not in the from volume, and s = 3 specifies no momentum flux in either the to or the from volume.

W7(R) Subcooled discharge coefficient. This quantity is applied only to subcooled liquid choked flow calculations. The quantity must be > 0.0 and ≤ 2.0. If W7, W8, and W9 are missing, then W7, W8, and W9 are set to 1.0.

W8(R) Two-phase discharge coefficient. This quantity is applied only to two-phase choked flow calculations. The quantity must be > 0.0 and ≤ 2.0. If W7 is entered, and W8 and W9 are missing, then W8 and W9 are set to 1.0.

W9(R) Superheated discharge coefficient. This quantity is applied only to superheated vapor/gas choked flow calculations. The quantity must be > 0.0 and $\leq$ 2.0. If W7 and W8 are entered, and W9 is missing, then W9 is set to 1.0.

7.4.2 Card CCC0110, Single-Junction Diameter and CCFL Data

This card is optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to specify only the junction hydraulic diameter for the interphase drag calculation (i.e., f = 0 in Word 6 of Cards CCC0101 through CCC0109), then, the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If this card is being used for the CCFL model (i.e., f = 1 in Word 6 of Cards CCC0101 through CCC0109), then enter all four words for the appropriate CCFL model if values different from the default values are desired.

W1(R) Junction hydraulic diameter, D_j (m, ft). This quantity is the junction hydraulic diameter used in the CCFL correlation equation, interphase drag, form loss Reynolds number, and jet junction model. This number must be $\geq$ 0. This number should be computed from $4.0 \bullet \left(\frac{\text{junction area}}{\text{wetted perimeter}}\right)$. If zero is entered or if the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{junction area}}{\pi}\right)^{0.5}$. See Word 3 of Cards CCC0101 through CCC0109 for the junction area.

W2(R) Flooding correlation form, β. If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be $\geq$ 0 and $\leq$ 1. The default value is 0 (Wallis form). See Section 3 of Volume I for details of the model.

W3(R) Vapor/gas intercept, c. This quantity is the vapor/gas intercept used in the CCFL correlation (when $H_f^{1/2} = 0$) and must be > 0. The default value is 1.

W4(R) Slope, m. This quantity is the slope used in the CCFL correlation and must be > 0. The default value is 1.

7.4.3 Card CCC0111, Single-Junction Form Loss Data

This card is optional. The user-specified form loss coefficients are given in Words 4 and 5 of Card CCC0101 if this card is not entered. If this card is entered, the form loss coefficients depend on the flow conditions and are calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficients; A_F, A_R, B_F, B_R, C_F, and C_R are user-specified constants. A_F and A_R are Words 4 and 5 of Cards CCC0101 through CCC0109; B_F, B_R, C_F, and C_R are Words 1, 2, 3, and 4 of this card (CCC0111); and Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculations, then enter all four words for the appropriate expression.

W1(R) B_F ($\geq$ 0). This quantity must be greater than or equal to zero.

W2(R) C_F ($\geq$ 0). This quantity must be greater than or equal to zero.

W3(R) B_R ($\geq$ 0). This quantity must be greater than or equal to zero.

W4(R) C_R ($\geq$ 0). This quantity must be greater than or equal to zero.

7.4.4 Card CCC0113, Single-Junction Face Placement

This card is optional. It is used to improve the graphical display of the hydrodynamic nodes. It is used to resolve problems with converging and diverging flows, that is, multiple junctions attached to the same face of a volume. With the standard input, each junction attached to the same face of a volume would be superimposed on the graphical display since each junction would be attached to the center of the volume face. For junctions with this card, the point of leaving the “from” volume and entering the “to” volume is allowed to be other than the center of the faces. The volume face is perpendicular to one of the coordinate directions. The attachment position is given by specifying the coordinates in the remaining two directions. Four words are entered on the card; two words for the coordinates for the “from” face, and two words for the two coordinates for the “to” face. The coordinates are entered in the order x, then y, then z, skipping the coordinate direction perpendicular to the face. The values are dimensionless. The actual coordinates are given by these values times the position change in moving from the volume center to the face in that direction. A value of 0.0 means no change from the center of the volume in that direction, and 1.0 means move to the edge of the volume in that direction. Positive or negative numbers can be entered, and the sign indicates moving in the positive or negative direction along that coordinate. A value greater than 1.0 can be used to get separation; the maximum allowed value is 25.0. The default is 0.0.

W1(R) First remaining coordinate value for the “from” face (dimensionless).

W2(R) Second remaining coordinate value for the “from” face (dimensionless).

W3(R) First remaining coordinate value for the “to” face (dimensionless).

W4(R) Second remaining coordinate value for the “to” face (dimensionless).

7.4.5 Card CCC0201, Single-Junction Initial Conditions

This card is required for single-junction components.

W1(I) Control word. If zero, the next two words are velocities; if one, the next two words are mass flow rates.

W2(R) Initial liquid velocity or initial liquid mass flow rate. This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lb_m/s), depending on the control word.

W3(R) Initial vapor/gas velocity or initial vapor/gas mass flow rate. This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lb_m/s), depending on the control word.

W4(R) Interface velocity (m/s, ft/s). Enter zero.

7.5 Time-Dependent Junction Component

This component is indicated by TMDPJUN for Word 2 on Card CCC0000. For major edits, minor edits, and plot variables, the junction in the time-dependent junction component is numbered as CCC000000.

7.5.1 Card CCC0101, Time-Dependent Junction Geometry

This card is required for time-dependent junction components.

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. An old or an expanded format can be used to connect volumes. In the old format (only allowed for connection to 1-D components), use CCC000000 if the connection is to the inlet side of the component and use CCC010000 if the connection is to the outlet side of the component. In the expanded format, the connection code for 1-D components is CCCXX000F [where CCC is the component number, XX is the volume number (greater than 00 and less than 100) for pipes/annuli/pressurizers, XX is 00 for all other 1-D components, and F indicates the face number]. A nonzero F specifies the expanded format. The number F equal to 1 and 2 specifies the inlet and outlet faces for the first coordinate direction (x or r), which is a 1-D volume's coordinate direction (x) (see Section 2.1). The number F equal to 3 through 6 specifies crossflow (y or z) for 1-D volumes. The number F equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction (y or θ); F equal to 5 and 6 would do the same for the third coordinate direction (z). For connecting to a time-dependent volume using the old format, both CCC000000 and CCC010000 are allowed. For connecting to a time-dependent volume using the expanded format, only the number F equal to 1 or 2 is allowed. Section 4.4 in this Appendix discusses this further.

W2(I) To connection code to a component. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.

W3(R) Junction area (m^2, ft^2). If zero, the area is set to the minimum flow area of the adjoining volumes. There are no junction area restrictions for time-dependent junctions.

W4(I) Junction control flags. This word has the packed format jefvcahs. It is not necessary to input leading zeros. This word is optional. If this word is not entered, jefvcahs is set to 00000000.

The digit j is not used and should be input as zero (j = 0). The jet junction model is not used.

The digit e specifies the modified PV term in the energy equations; e = 0 specifies that the modified PV term will not be applied, and e = 1 specifies the modified PV term will be applied.

The digit f is not used and should be input as zero (f = 0). The CCFL model is not used.

The digit v is not used and should be input as zero (v = 0). The stratification entrainment/pullthrough model is not used.

The digit c is not used and should be input as zero (c = 0). The choking model is not used.

The digit a is not used and should be input as zero (a = 0). The abrupt area change model is not used.

The digit h is not used and should be input as zero (h = 0). The homogeneous model is not used.

The digit s is not used and should be input as zero (s = 0). The momentum flux model is not used.

7.5.2 Card CCC0113, Time-Dependent Junction Face Placement Data

This card is optional. It is used to improve the graphical display of the hydrodynamic nodes. It is used to resolve problems with converging and diverging flows, that is, multiple junctions attached to the same face of a volume. With the standard input, each junction attached to the same face of a volume would be superimposed on the graphical display since each junction would be attached to the center of the volume face. For junctions with this card, the point of leaving the “from” volume and entering the “to” volume is allowed to be other than the center of the faces. The volume face is perpendicular to one of the coordinate directions. The attachment position is given by specifying the coordinates on the remaining two directions. Four words are entered on the card; two words for the coordinates for the “from” face, and two words for the two coordinates for the "to" face. The coordinates are entered in the order x, then y, then z, skipping the coordinate direction perpendicular to the face. The values are dimensionless. The actual coordinates are given by these values times the position change in moving from the volume center to the face in that direction. A value of 0.0 means no change from the center of the volume in that direction, and 1.0 means move to the edge of the volume in that direction. Positive or negative numbers can be entered, and the sign indicates moving in the positive or negative direction along that coordinate. A value greater than 1.0 can be used to get separation; the maximum allowed value is 25.0. The default is 0.0.

W1(R) First remaining coordinate value for the "from" face (dimensionless).

W2(R) Second remaining coordinate value for the "from" face (dimensionless).

W3(R) First remaining coordinate value for the "to" face (dimensionless).

W4(R) Second remaining coordinate value for the "to" face (dimensionless).

7.5.3 Card CCC0200, Time-Dependent Junction Data Control Word

This card is optional. If this card is missing, the second and third words of the time-dependent data are assumed to be velocities.

W1(I) Control word. If zero, the second and third words of the time-dependent junction data in Cards CCC0201 through CCC0299 are velocities. If one, the second and third words of the time-dependent junction data in Cards CCC0201 through CCC0299 are mass flow rates. In both cases, the fourth word is interface velocity and should be entered as zero.

W2(I) Table trip number. This word is optional. If missing or zero and Word 3 is missing, no trip is used, and the time argument is the advancement time. If nonzero and Word 3 is missing, this number is the trip number and the time argument is -1.0×10^{308} if the trip is false, and the advancement time minus the trip time if the trip is true.

W3(A) Alphanumeric part of variable request code. This quantity is optional. If not present, time is the search variable. If present, this word and the next are a variable request code that specifies the search argument for the table lookup and interpolation. If the trip number is zero, the specified argument is always used. If the trip number is nonzero, -1.0×10^{308} is used if the trip is false, and the specified argument is used if the trip is true. TIME can be selected, but note that the trip logic is different than if this word is omitted. The variable MFLOWJ should not be used as a search variable; a user-initialized control variable that uses MFLOWJ should be used instead (See Volume V).

W4(I) Numeric part of variable request code. This is assumed zero if missing.

7.5.4 Cards CCC0201 through CCC0299, Time-Dependent Junction Data

These cards are required for time-dependent junction components. A set of data consists of the search variable (e.g., time) followed by the required data indicated by control Word 1 on Card CCC0200. The card numbers need not be consecutive, but the value of the search variable in a succeeding set must be equal to or greater than the value in the previous set. One or more sets of data up to 5,000 sets, may be entered. Enter only the minimum number of words required. Linear interpolation is used if the search argument lies between the search variable entries. End-point values are used if the argument lies outside the table values. Only one set is needed if constant values are desired, and computer time is reduced when only one set is entered. Step changes can be accommodated by entering the two adjacent sets with the same search variable values or an extremely small difference between them. Given two identical argument values, the set selected will be the closest to the previous argument value. Sets may be entered one or more per card and may be split across cards. The total number of words must be a multiple of the set size. For large sets of data, continuation cards will be needed. The total number of words on a card and its continuation cards may not exceed 2,047.

Inputting time-dependent junction tables where the search variable is a thermodynamic variable from some other component can run into difficulties if the component number is such that the time-dependent junction is initialized before the component providing the needed search variable. This problem can be circumvented by always referencing lower-number components in a search variable. Another reliable fix for this is to make the search variable a control system output in the desired units. while the thermodynamic variable is the control system input in code internal (SI) units. The control system initial values can be set to the desired initial value of the search variable, and this will be used by the time-dependent table.

When doing a single-phase problem and entering velocities here, the same value should be entered for both liquid and vapor/gas velocities. When doing a single-phase problem and entering mass flow rates here, the correct value should be entered for either liquid or vapor/gas (whichever single-phase is being modeled) and the other entry should be zero.

If the user wants to specify the vapor/gas void fraction as a function of time in the time-dependent volume, and the total mass flow rate as a function of time in the time-dependent junction, then both the phasic (vapor/gas and liquid) mass flow rates must be calculated and entered in these cards.

A time dependent junction can be used to model either an inflow or an outflow condition; however, care is required in modeling outflows. A time-dependent junction is analogous to a positive displacement pump in that the flow is independent of the system pressure. In the case of outflow, it is possible to specify a greater outflow than inflow to a volume or even outflow that will exhaust the volume. In this case, a numerical failure will result when the equivalent of a negative density is calculated. For this reason, modeling outflows using a time-dependent junction is not recommended.

W1(R) Search variable (e.g., time).

W2(R) Liquid velocity or liquid mass flow rate. This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lb_m/s), depending on control Word 1 of Card CCC0200.

W3(R) Vapor/gas velocity or vapor/gas mass flow rate. This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lb_m/s), depending on control Word 1 of Card CCC0200.

W4(R) Interface velocity (m/s, ft/s). Enter zero.

As described above, sets may be entered one or more per card.

7.6 Pipe, Annulus, or Pressurizer Component

A pipe component is indicated by PIPE and an annulus component is indicated by ANNULUS for Word 2 on Card CCC0000. A pressurizer component is indicated by PRIZER for Word 2 on Card CCC0000. The PIPE and ANNULUS components are similar, except that the ANNULUS component must be vertical and all the liquid is in the film (i.e., no drops) when in the annular mist flow regime. The ANNULUS component can be used to model a downcomer. The remaining input for both components is identical. The PRIZER component can be used to model a noncondensable driven pressurizer or a vapor/gas-liquid pressurizer; it requires additional input on Card CCC0001. More than one junction may be connected to the inlet or outlet of a PIPE, ANNULUS, or PRIZER. If an end has no junctions, that end is considered a closed end. For major edits, minor edits, and plot variables, the volumes in the pipe or annulus or pressurizer component are numbered as CCCXX0000, where XX is the volume number (greater than 00 and less than 100). The junctions in the pipe or annulus or pressurizer component are numbered as CCCXX0000, where XX is the junction number (greater than 00 and less than 99).

The general input for a pipe or annulus or pressurizer component assumes that the pipe or annulus or pressurizer has at least two volumes with one junction separating the two volumes. It is possible to input a one-volume pipe or annulus or pressurizer. In order to implement this special case, the user must set the number of volumes and the volume number on the volume cards to one. In addition, the user should not input any of the junction cards.

The volumes in a pipe or annulus or pressurizer are usually considered one-dimensional components and flow in the volumes is along the x-coordinate. Crossflow junctions can connect to any of the pipe or annulus or pressurizer volumes in the y- and z-coordinate directions using a form of the momentum equation that does or does not include momentum flux terms. It is also possible to connect external junctions to the x-coordinate direction faces of any of the pipe or annulus or pressurizer volumes using a form of the momentum equation that does or does not include the momentum flux terms. It is also possible to include or not include the momentum flux terms in internal pipe or annulus or pressurizer junctions.

7.6.1 Card CCC0001, Pipe, Annulus, or Pressurizer Information

This card is required.

W1(I) Number of volumes, nv. The number nv must be greater than zero and less than 100. The number of associated junctions internal to these components is nv-1. The outer junctions are described by other components.

W2(I) Surgeline connection junction number of the junction connecting the bottom volume of the pressurizer to the surge line volume. This word must have the same format as in the major edits, minor edits, and plot variables. The bottom volume of the pressurizer must be the “from” volume and the surgeline volume must be the “to” volume when specifying this surgeline connection junction connecting the two. This input is required for a PRIZER component and must not be entered for PIPE or ANNULUS components.

W3(R) User-specified constant interfacial heat transfer coefficient for liquid (W/m^2-K, Btu/hr-ft^2-^oF) in the vertically stratified flow regime and the level tracking flow regime. This word is optional for a PRIZER component and must not be entered for PIPE or ANNULUS components. If this word is less than or equal to zero, the interfacial heat transfer coefficient for liquid from the correlation is used. The default value is zero.

W4(R) User-specified constant interfacial heat transfer coefficient for vapor/gas (W/m^2-K, Btu/hr-ft^2-^oF) in the vertically stratified flow regime and the level tracking flow regime. This word is optional for a PRIZER component and must not be entered for PIPE or ANNULUS components. If this word is less than or equal to zero, the interfacial heat transfer coefficient for vapor/gas from the correlation is used. The default value is zero.

W5(I) User-specified identifier for a multiplier on the code calculated fraction of the liquid in the film in the annular-mist flow regime. This word is optional for a PRIZER component and must not be entered for PIPE and ANNULUS components. A value of 1 through 999 indicates a general table of type REAC-T for use to specify the multiplier whose number is the entered number (Note: A general table of type REAC-T is used to prevent undesirable units conversion, since no British or SI units conversion is done for REAC-T entries). A value of 10001 through 19999 indicates the multiplier will be obtained from a control variable whose identification number is the entered number minus 10000. A value of zero means that the multiplier of 1.0 will be used. A value of zero from the table or control variable means that all of the available liquid is in droplets in the annular-mist flow regime. The default value is zero.

W6(I) User-specified identifier for a multiplier on the interfacial heat transfer coefficients for both liquid and vapor/gas in the vertically stratified flow regime and the level tracking flow regime. This word is optional for the PRIZER component and may not be entered for PIPE and ANNULUS components. A value of 1 through 999 indicates a general table of type REAC-T for use to specify the multiplier (Note: A general table of type REAC-T is used to prevent undesirable units conversion, since no British or SI units conversion is done for REAC-T entries). A value of 10001 through 19999 indicates the multiplier will be obtained from a control variable whose identification number is the entered value minus 10000. A value of zero means that a multiplier of 1.0 will be used. The default value is zero.

W7(I) Pressurizer spray droplet diameter. This word is optional for a PRIZER component and must not be entered for PIPE or ANNULUS components. This word specifies the droplet diameter in the annular-mist and mist flow regimes. A value of zero specifies that the value computed from the correlations in the code are to be used. The default value is zero.

W8(I) Pressurizer spray junction identifier. This word is optional for a PRIZER component and must not be entered for PIPE or ANNULUS components. This word specifies the identifier of the pressurizer spray junction. This word must have the same format as in the major edits, minor edits, and plot variables. A volume in the pressurizer component must be the "to" volume for this junction so that positive flow in the junction is into the pressurizer component. A non-zero value for this input activates the spray induced, enhanced condensation model in the vertical stratification and level tracking flow regimes. These flow regimes are active for the pressurizer volume containing the liquid level. The default value is zero.

W9(R) Pressurizer spray mixing coefficient. This word is optional for a PRIZER component and must not be entered for PIPE or ANNULUS components. This word specifies the spray mixing coefficient used in the spray induced, enhanced condensation model. The default value is zero.

7.6.2 Card CCC0003, Pipe, Annulus, or Pressurizer Magnetohydrodynamics (MHD) Card

This card is optional. The card is needed to activate the MHD pressure drop effect for this component. SI units must be used for both input and output. This component must contain either the fluid lithium, lithium-lead, or NaK.

W1(R) Magnetic field (B-field) strength (Wb/m^2).

W2(R) Duct wall electrical conductivity (ohm^{-1}m^{-1}).

W3(R) Duct wall thickness (m).

W4(I) Duct geometry type. This word is optional. For a circular duct, this word is 1. For a square duct, this word is 2. If this word is not entered, the default is 1.

W5(I) Fringe volume flag. This word is optional. A fringe volume uses a non-uniform (spatially-varying) magnetic field. The non-uniform field distribution is computed automatically from an internal submodel in the implementation of the MHD model. A non-fringe volume uses a uniform (constant) magnetic field. A fringe volume can only exist at the inlet or outlet end of the component. If the first component volume (inlet end) is a fringe volume, this word is -1. If the last component volume (outlet end) is a fringe volume, this word is +1. If both the first and last volumes (inlet and output end) are fringe volumes, this word is 2. If neither the first nor the last component volumes (inlet end and outlet ends) are fringe volumes, this word is 0. Each component fringe volume must have a length equal to 10 times the volume's half-width (within 1%). For a circular duct, the volume half-width is set equal to 1/2 the hydrodynamic diameter. For a square duct, the volume half-width is set equal to the square root of the flow area. If this word in not entered, the default is 0.

7.6.3 Cards CCC0101 through CCC0199, Pipe, Annulus, or Pressurizer X-Coordinate Volume Flow Areas

The format is two words per set in sequential expansion format for nv sets. These cards are required, and the card numbers need not be consecutive. The words for one set are

W1(R) Volume flow area in the x-direction (m^2, ft^2).

W2(I) Volume number.

7.6.4 Cards CCC1601 through CCC1699, Pipe, Annulus, or Pressurizer Y-Coordinate Volume Flow Areas

The format is two words per set in sequential expansion format for nv sets. These cards are optional and if entered activate the y-coordinate for each volume and allow the full one-dimensional momentum equations to be used in connections to the y-faces. The card numbers need not be consecutive. The words for one set are

W1(R) Volume flow area in the y-direction (m^2, ft^2). If these cards are missing, this y-direction volume flow area is computed from (volume of volume)/(y-direction length).

W2(I) Volume number.

7.6.5 Cards CCC1701 through CCC1799, Pipe, Annulus, or Pressurizer Z-Coordinate Volume Flow Areas

The format is two words per set in sequential expansion format for nv sets. These cards are optional and if entered activate the z-coordinate for each volume and allow the full one-dimensional momentum equations to be used in connections to the z-faces. The card numbers need not be consecutive. The words for one set are

W1(R) Volume flow area in the z-direction (m^2, ft^2). If these cards are missing, this z-direction volume flow area is computed from (volume of volume)/(z-direction length).

W2(I) Volume number.

7.6.6 Cards CCC0201 through CCC0299, Pipe, Annulus, or Pressurizer Junction Flow Areas

These cards are optional, and, if entered, the card numbers need not be consecutive. The format is two words per set in sequential expansion format for nv-1 sets.

W1(R) Internal junction flow area in the x-direction (m^2, ft^2). If cards are missing or a word is zero, the junction flow area is set to the minimum area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or less than the minimum of the adjacent volume areas. There is no restriction for smooth area changes.

W2(I) Junction number.

7.6.7 Cards CCC0301 through CCC0399, Pipe, Annulus, or Pressurizer X-Coordinate Volume Lengths

These cards are required. The format is two words per set in sequential expansion format for nv sets. Card numbers need not be consecutive.

W1(R) Volume length in the x-direction (m, ft).

W2(I) Volume number.

7.6.8 Cards CCC1801 through CCC1899, Pipe, Annulus, or Pressurizer Y-Coordinate Volume Lengths

These cards are optional and, if entered, activate the y-coordinate for each volume and allow the full one-dimensional momentum equation for connections to the y-faces. The format is two words per set in sequential expansion format for nv sets. Card numbers need not be consecutive.

W1(R) Volume length in the y-direction (m, ft). If these cards are missing and Cards CCC1601 through CCC1699 are missing, this y-direction length is computed from $2.0 \bullet \left(\frac{\text{x} - \text{direction volume flow area}}{\pi}\right)^{0.5}$. If these cards are missing and Cards CCC1601 through CCC1699 are present, this y-direction length is computed from (volume of volume)/(y-direction flow area).

W2(I) Volume number.

7.6.9 Cards CCC1901 through CCC1999, Pipe, Annulus, or Pressurizer Z-Coordinate Volume Lengths

These cards are optional and, if entered, activate the z-coordinate for each volume and allow the full one-dimensional momentum equation for connections to the z-faces. The format is two words per set in sequential expansion format for nv sets. Card numbers need not be consecutive.

W1(R) Volume length in the z-direction (m, ft). If these cards are missing and Cards CCC1701 through CCC1799 are missing, this z-direction length is computed from $2.0 \bullet \left(\frac{\text{x – direction volume flow area}}{\pi}\right)^{0.5}$. If these cards are missing and Cards CCC1701 through CCC1799 are present, this z-direction length is computed from (volume of volume)/(z-direction volume flow area).

W2(I) Volume number.

7.6.10 Cards CCC2901 through CCC2999, Pipe, Annulus, or Pressurizer Elbow/Spiral Angle/Radius of Curvature and Inclination Angle

This section of input has been implemented, however the use of the input quantities in the code has only been implemented to modify the geometry. The use of the input quantities in the code has not yet been implemented to modify the physics.

These cards are optional and allow the description of a curved tube or spiral. The card format is three words per set in sequential expansion format for nv sets. Card numbers need not be consecutive.

W1(R) Angle of curved tube if a positive number (degrees) or radius of curvature (m, ft) if entered as a negative number. A zero indicates a straight section of the component. The angle of the curved pipe is the angle formed by the radius of curvature drawn from the center of the inlet face to the radius of curvature drawn from the center of the outlet face. The radius of curvature is a positive number; the minus sign is only to distinguish it from the angle input. Using ζ for the angle of curved component, r for the radius of curvature, and l for the volume length, these quantities are related by $l = r\varsigma\frac{\pi}{180}$.

For a straight component, the x-coordinate or normal flow direction of the volume is initially aligned along the space x-coordinate. A curved component is initially positioned in the horizontal r-θ plane, which coincides with the fixed x-y plane. The positive flow direction is in the counterclockwise azimuthal direction, and the radius of curvature extends from the r-θ origin to the center of the flow area. The inlet face is in the x-z plane. This initially aligned figure can then be rotated to the desired orientation for placement in the hydrodynamic system.

W2(R) Inclination angle (degrees). This angle is the inclination of a spiral. Entering zero specifies a curved component. Entering a nonzero specifies a spiral and this quantity is the angle of change in the fixed z coordinate. This number must be greater than or equal to 0.0 and less than 90.0.

W3(I) Volume number.

7.6.11 Cards CCC0401 through CCC0499, Pipe, Annulus, or Pressurizer Volume Volumes

The format is two words per set in sequential expansion format for nv sets. Card numbers need not be consecutive.

W1(R) Volume (m^3, ft^3). If these cards are missing, volumes equal to zero are assumed. The code requires that each volume equal the x-direction flow area times the x-direction length. If activated, the code also requires each volume equal the y-direction flow area times the y-direction length, and each volume equal the z-direction flow area times the z-direction length. For any volume, at least two of the three quantities, x-direction area, the x-direction length, or volume, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the quantities are zero, the volume must equal the x-direction area times the x-direction length within a relative error of 0.000001. The same relative error check is done for the y- and z-directions. If both the y-direction area and y-direction length are not entered or are zero, the y-direction length is computed from $2.0 \bullet \left(\frac{\text{x} - \text{direction flow area}}{\pi}\right)^{0.5}$ and the y-direction flow area is computed from $\frac{\text{volume of volume}}{\text{y-direction length}}$. The same is true for the z-direction.

W2(I) Volume number.

7.6.12 Cards CCC0501 through CCC0599, Pipe, Annulus, or Pressurizer Volume Azimuthal Angles

These cards are optional, and, if not entered, the angles are set to zero. The format is two words per set in sequential expansion format for nv sets, and card numbers need not be consecutive.

W1(R) (horizontal) angle (degrees). The absolute value of this angle must be ≤ 360 degrees and is defined as a positional quantity. This angle is in the horizontal x-y plane. The angle 0 degrees is on the x axis, and the angle 90 degrees is on the y axis. Positive angles are rotated from the x axis toward the y axis. This quantity is not used in the calculation but is specified for automated drawing of nodalization diagrams.

W2(I) Volume number.

7.6.13 Cards CCC0601 through CCC0699, Pipe, Annulus, or Pressurizer Volume Inclination Angles

These cards are required. The format is two words per set in sequential expansion format for nv sets, and card numbers need not be consecutive.

W1(R) Inclination (vertical) angle (degrees). The absolute value of this angle must be ≤ 90 degrees angle 0 degrees is horizontal; positive angles have an upward direction, i.e., the inlet is at a lower elevation. This angle is used in the flow regime determination, in the interphase drag calculation, and for automated drawing of nodalization diagrams. When the absolute value of the inclination (vertical) angle is less than or equal to 30 degrees, the horizontal flow regime map is used. When the absolute value of the inclination (vertical) angle is greater than or equal to 60 degrees, the vertical flow regime is used. Between 30 and 60 degrees, interpolation is used.

W2(I) Volume number.

7.6.14 Cards CCC0701 through CCC0799, Pipe, Annulus, or Pressurizer Volume X-Coordinate Position or Elevation Changes

These cards are optional. If these cards are missing, the x-coordinate position changes or elevation changes are computed from the x-coordinate volume length and a rotation matrix computed from the angle information. If these cards are entered, the entered data becomes the x-coordinate position change or elevation change data. The card format is two words per set in sequential expansion format up to nv sets, and card numbers need not be consecutive.

W1(R) Elevation change. This is the coordinate position change along the fixed z-axis due to the traverse from inlet to outlet along the local x-coordinate, Δ_{zx} (m, ft). A positive value is an increase in elevation. The absolute value of this quantity must be less than or equal to the volume length. If the inclination (vertical) angle is zero, this quantity must be zero. If the inclination (vertical) angle is nonzero, this quantity must be nonzero and have the same sign. The elevation change is used in the gravity head and checking loop closure. See Section 2.4.1 of Volume II of the manual for further discussion. A calculated elevation angle is determined by the arcsin of the ratio of the elevation change (this word) and the volume length (Word 1 on Cards CCC0301 through CCC0309). This calculated elevation angle is used in the additional stratified force term.

W2(I) Volume number.

7.6.15 Cards CCC0801 through CCC0899, Pipe, Annulus, or Pressurizer

Volume X-Coordinate Friction Data

These cards are required. The card format is three words per set for nv sets, and card numbers need not be consecutive.

W1(R) Wall roughness in the x-direction (m, ft). The x-direction wall roughness is limited to be greater than or equal to $1.0x10^{-9}$ times the x-direction hydraulic diameter. If zero, the x-direction wall roughness is computed from $1.0x10^{-9}$ times the x-direction hydraulic diameter.

W2(R) Hydraulic diameter in the x-direction (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{x-direction volume flow area}}{\text{x-direction wetted perimeter}}\right)$. If zero, the x-direction hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{x-direction volume flow area}}{\pi}\right)^{0.5}$. A check is made to ensure that the wall roughness in the x-direction is less than half the x-direction hydraulic diameter. See Word 1 on Cards CCC0101 through CCC0109 for the x-direction volume flow area.

W3(I) Volume number.

7.6.16 Cards CCC2301 through CCC2399, Pipe, Annulus, or Pressurizer Volume Y-Coordinate Friction Data

These cards are required if the volume flow area or volume length data was entered for the y-coordinate. If the cards are not entered, the y-direction wall roughness defaults to zero and the default y-direction hydraulic diameter is computed from $4.0 \bullet \left(\frac{\text{y} - \text{direction volume flow area}}{\pi \bullet \text{x} - \text{direction volume flow area}}\right)^{0.5}$. See Section 2.4 of this volume of the manual. The card format is three words per set for nv sets, and card numbers need not be consecutive.

W1(R) Wall roughness in the y-direction (m, ft). The y-direction wall roughness is limited to be greater than or equal to $1.0x10^{-9}$ times the y-direction hydraulic diameter. If zero, the y-direction wall roughness is computed from $1.0x10^{-9}$ times the y-direction hydraulic diameter.

W2(R) Hydraulic diameter in the y-direction (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{y–direction volume flow area}}{\text{y–direction wetted perimeter}}\right)$. If zero, the y-direction hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{y–direction volume flow area}}{\pi \bullet \text{x} - \text{direction volume flow area}}\right)^{0.5}$. See Section 2.4 of this volume of the manual. A check is made to ensure that the y-direction wall roughness is less than half the y-direction hydraulic diameter. See Word 1 on cards CCC1601 through CCC1699 for the y-direction volume flow area.

W3(R) Volume number.

7.6.17 Cards CCC2401 through CCC2499, Pipe, Annulus, or Pressurizer Volume Z-Coordinate Friction Data

These cards are required if the volume flow area or volume length data was entered for the z-coordinate. If the cards are not entered, the z-direction wall roughness defaults to zero and the z-direction default hydraulic diameter is computed from $4.0 \bullet \left(\frac{z - \text{direction volume flow area}}{\pi \bullet x - \text{direction volume flow area}}\right)^{0.5}$. See Section 2.4 of this volume of the manual. The card format is three words per set for nv sets, and card numbers need not be consecutive.

W1(R) Wall roughness in the z-direction (m, ft). The z-direction wall roughness is limited to be greater than or equal to 1.0×10^{-9} times the z-direction hydraulic diameter. If zero, the z-direction wall roughness is computed from 1.0×10^{-9} times the z-direction hydraulic diameter.

W2(R) Hydraulic diameter in the z-direction (m, ft). This should be computed from $4.0 \bullet \left(\frac{z\text{–direction volume flow area}}{z\text{–direction wetted perimeter}}\right)$. If zero, the z-direction hydraulic diameter is computed from $2.0 \bullet \left(\frac{z\text{–direction volume flow area}}{\pi \bullet x - \text{direction volume flow area}}\right)^{0.5}$. See Section 2.4 of this volume of the manual. A check is made to ensure that the z-direction wall roughness is less than half the z-direction hydraulic diameter. See Word 1 on cards CCC1701 through CCC1799 for the z-direction volume flow area.

W3(R) Volume number.

7.6.18 Cards CCC2501 through CCC2599, Pipe, Annulus, or Pressurizer Volume Additional Wall Friction Data

These cards are optional. If these cards are not entered, the default values are 1.0 for the laminar shape factor and 0.0 for the viscosity ratio exponent. The card format is seven words per set in sequential expansion format for nv sets and card numbers need not be consecutive. A description of this input is presented in Section 3 of Volume I.

W1(R) Shape factor for coordinate direction 1.

W2(R) Viscosity ratio exponent for coordinate direction 1.

W3(R) Shape factor for coordinate direction 2.

W4(R) Viscosity ratio exponent for coordinate direction 2.

W5(R) Shape factor for coordinate direction 3.

W6(R) Viscosity ratio exponent for coordinate direction 3.

W7(I) Volume number.

7.6.19 Cards CCC2601 through CCC2699, Pipe, Annulus, or Pressurizer Volume Alternate Turbulent Wall Friction Data

These cards are optional. These cards allow the specification of user-defined turbulent friction factors for selected volumes and coordinate directions. The turbulent friction factor has the form $f = A + B(Re)^{-C}$ where A, B, and C are entered for each coordinate of each volume. If these cards are not entered, the standard turbulent friction factor is used for all coordinates of all volumes. If the cards are entered, the standard turbulent friction factor can be selected for a particular volume and coordinate direction by entering zeros for the three quantities. The card format is ten words per set in sequential expansion format for nv sets and card numbers need not be consecutive.

W1(R) A for coordinate direction 1.

W2(R) B for coordinate direction 1.

W3(R) C for coordinate direction 1.

W4(R) A for coordinate direction 2.

W5(R) B for coordinate direction 2.

W6(R) C for coordinate direction 2.

W7(R) A for coordinate direction 3.

W8(R) B for coordinate direction 3.

W9(R) C for coordinate direction 3.

W10(I) Volume number.

7.6.20 Cards CCC0901 through CCC0999, Pipe, Annulus, or Pressurizer

Junction Loss Coefficients

These cards are optional and if missing, the energy loss coefficients are set to zero. The card format is three words per set in sequential expansion format for nv-1 sets, and card numbers need not be consecutive.

W1(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or zero. Note: a variable loss coefficient may be specified (see Section 7.6.30 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W2(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. Note: a variable loss coefficient may be specified (see Section 7.6.30 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W3(I) Junction number.

7.6.21 Cards CCC1001 through CCC1099, Pipe, Annulus, or Pressurizer Volume X-Coordinate Control Flags

These cards are required. The card format is two words per set in sequential expansion format for nv sets, and card numbers need not be consecutive.

W1(I) Volume control flags. This word has the packed format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scaler oriented and coordinate direction oriented flags. Only one value for a scaler oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. These words enter the scaler oriented flags and the x-coordinate flags for each volume in the component.

. The digit t specifies whether the thermal front tracking model is to be used; t = 0 specifies that the front tracking model is not to be used for the volume, and t = 1 specifies that the front tracking model is to be used for the volume. The thermal front tracking model can only be applied to vertically-oriented components.

The digit l specifies whether the mixture level tracking model is to be used; l = 0 specifies that the level model not be used for the volume, and l = 1 specifies that the level model be used for the volume. The mixture level tracking model can only be applied to vertically-oriented components.

The digit p specifies whether the water packing scheme is to be used; p = 0 specifies that the water packing scheme is to be used for the volume, and p = 1 specifies that the water packing scheme is not to be used for the volume. The water packing scheme is recommended when modeling a pressurizer. The water packing scheme is only applied to vertically oriented volumes.

The digit v specifies whether the vertical stratification model is to be used.,v = 0 specifies that the vertical stratification model is to be used for the volume, and v = 1 specifies that the vertical stratification model is not to be used for the volume. The vertical stratification model is recommended when modeling a pressurizer. The vertical stratification model is only applied to vertically oriented volumes.

The digit b specifies the interphase friction that is used; b = 0 specifies that the pipe interphase friction model will be applied, b = 1 specifies that the rod bundle interphase friction model will be applied, and b = 2 specifies that the ORNL ANS narrow channel model will be applied. (Cards CCC3101 through CCC3199 required). The b = 1 option and the b = 2 option are only applied to vertically oriented volumes.

The digit f specifies whether wall friction is to be computed; f = 0 specifies that wall friction effects are to be computed along the x-coordinate of the volume, and f = 1 specifies that wall friction effects are not to be computed along the x-coordinate of the volume.

The digit e specifies if nonequilibrium or equilibrium is to be used; e = 0 specifies that a nonequilibrium (unequal temperature) calculation is to be used, and e = 1 specifies that an equilibrium (equal temperature) calculation is to be used. Equilibrium volumes should not be connected to nonequilibrium volumes. The equilibrium option is provided only for comparison to other codes.

W2(I) Volume number.

7.6.22 Cards CCC2701 through CCC2799, Pipe, Annulus, or Pressurizer Volume Y-Coordinate Control Flags

W1(I) Volume control flags. This word has the general packed format tlpvbfe, but this word is limited to 00000f0 since it only enters the coordinate oriented flags for the y-direction.

The digit f specifies whether wall friction is to be computed; f = 0 specifies that wall friction effects are to be computed along the y-coordinate direction of the volume, and f = 1 specifies that wall friction effects are not to be computed along the y-coordinate direction of the volume.

W2(I) Volume number.

7.6.23 Cards CCC2801 through CCC2899, Pipe, Annulus, or Pressurizer Volume Z-Coordinate Control Flags

W1(I) Volume control flags. This word has the general packed format tlpvbfe, but this word is limited to 00000f0 since it only enters the coordinate oriented flags for the z-direction.

The digit f specifies whether wall friction is to be computed; f = 0 specifies that wall friction effects are to be computed along the z-coordinate direction of the volume, and f = 1 specifies that wall friction effects are not to be computed along the z-coordinate direction of the volume.

W2(I) Volume number.

7.6.24 Cards CCC1101 through CCC1199, Pipe, Annulus, or Pressurizer Junction Control Flags

These cards are required. The card format is two words per set in sequential expansion format for nv-1 sets, and card numbers need not be consecutive.

W1(I) Junction control flags. This word has the packed format jefvcahs. It is not necessary to input leading zeros.

The digit j is not used and should be input as zero (j = 0). The jet junction model is not used.

The digit e specifies the modified PV term in the energy equations; e = 0 specifies that the modified PV term will not be applied, and e = 1 specifies that the modified PV term will be applied.

The digit f specifies CCFL options; f = 0 specifies that the CCFL model will not be applied, and f = 1 specifies that the CCFL model will be applied.

The digit v is not used and should be input as zero (v = 0). The horizontal stratification entrainment/pullthrough model cannot be used.

The digit c specifies choking options; c = 0 specifies that the choking model will be applied, and c = 1 specifies that the choking model will not be applied.

The digit a specifies area change options; a = 0 specifies either a smooth area change or no area change, a = 1 specifies full abrupt area change model (code-calculated K_{loss}, area apportioning at a branch, restricted junction area, and extra interphase drag), and a = 2 specifies a partial abrupt area change model (no code-calculated K_{loss}, but includes area apportioning at a branch, restricted junction area, and extra interphase drag). It is recommended that the abrupt area change model (a = 1 or a = 2) be used at branches.

The digit h specifies nonhomogeneous or homogeneous; h = 0 specifies the nonhomogeneous (two-velocity momentum equations) option, and h = 1 or 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 1 or 2), the major edit printout will show a one.

The digit s specifies momentum flux options; s = 0 specifies momentum flux in both the to volume and the from volume, s = 1 specifies momentum flux in the from volume but not in the to volume, s = 2 specifies momentum flux in the to volume but not in the from volume. s = 3 specifies no momentum flux in either the to or the from volume. For this component, the option s = 0 is the usual recommendation (momentum flux in both volumes). The other options s = 1, 2, and 3 are included to allow consistency for this flag for other components (single-junction, branch junction, etc.).

W2(I) Junction number.

7.6.25 Cards CCC1201 through CCC1299, Pipe, Annulus, or Pressurizer Volume Initial Conditions

These cards are required. The card format is seven words per set in sequential expansion format for nv sets, and card numbers need not be consecutive.

W1(I) Control word. This word has the packed format εbt. It is not necessary to input leading zeros.

The digit ε specifies the fluid, where ε = 0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120 - 129 cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O, etc.). The default fluid is that set for the hydrodynamic system by Cards 120 through 129 or this control word in another volume in this hydrodynamic system. The fluid type set on Cards 120 through 129 or these control words must be consistent (i.e., not specify different fluids). If Cards 120 through 129 are not entered and all control words use the default ε = 0, then H_2O is assumed as the fluid.

The digit b specifies whether boron is present or not. The digit b = 0 specifies that the volume liquid does not contain boron; b = 1 specifies that a boron concentration in mass of boron per mass of liquid (which may be zero) is being entered after the other required thermodynamic information.

The digit t specifies how the following words are to be used to determine the initial thermodynamic state. Entering t equal to 0 through 3 specifies one component (vapor/liquid). Entering t equal to 4, 5, 6, or 8 allows the specification of two components (vapor/liquid and noncondensable gas).

With options t equal to 4, 5, 6, or 8, the names of the components of the noncondensable gas must be entered on Card 110, and the mass fractions of the components of the noncondensable gas are entered on Card 115. Cards CCC3201-CCC3299 may also be used for the mass fractions of the components of the noncondensable gas.

If t = 0, the next four words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor/gas specific internal energy (J/kg, Btu/lb_m), and vapor/gas void fraction. These quantities will be interpreted as nonequilibrium or equilibrium conditions, depending on the specific internal energies used to define the thermodynamic state. W6 should be 0.0.

If t = 1, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. W4, W5, and W6 should be 0.0.

If t = 2, the next two words are interpreted as pressure (Pa, lb_f/in^2) and static quality in equilibrium condition. W4, W5, and W6 should be 0.0.

If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in nonequilibrium or equilibrium conditions depending on the pressure and temperature used to define the thermodynamic state. W4, W5, and W6 should be 0.0.

The following options are used for input of noncondensable states. In all cases, the criteria used for determining the range of values for static quality are;

1. 1.0E-9 $\leq$ static quality $\leq$ 0.99999999, two-phase conditions

2. static quality < 1.0E-9 or static quality > 0.99999999, single-phase conditions.

The static quality is given by $M_g/(M_g + M_f)$, where $M_g = M_s + M_n$. Section 3.2 of Volume I of the manual discusses this further.

Noncondensable options are as follows:

If t = 4, the next three words are interpreted as pressure (Pa, lb_f/in^2), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static quality > 0.0 and ≤ 1.0, saturated noncondensables (100% relative humidity) will result. W5 and W6 should be 0.0. The temperature is restricted to be less than the saturation temperature at the input pressure and less than the critical temperature; otherwise an input error will occur. Setting static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable, 0% relative humidity) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option.

If t = 5, the next three words are interpreted as temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. Both the static and noncondensable qualities are restricted to be between 1.0E-9 and 0.99999999. W5 and W6 should be 0.0. Little experience has been obtained using this option, and it has not been checked out.

If t = 6, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor/gas specific internal energy (J/kg, Btu/lb_m), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the specific internal energies used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing (t = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume temperature is calculated from the noncondensable energy equation using the input vapor/gas specific internal energy.

If t = 8, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid temperature (K, ^oF), vapor/gas temperature (K, ^oF), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the temperatures used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume specific internal energy is calculated from the noncondensable energy equation using the input vapor/gas temperature.

W2-W6(R) Quantities as described under Word 1. Five quantities must be entered, and zeros should be entered for unused quantities. If any control word (Word 1) indicates that boron is present, Cards CCC2001 through CCC2099 must be entered to define the initial boron concentrations. Boron concentrations are not entered in Words 2 through 6.

W7(I) Volume number.

7.6.26 Cards CCC2001 through CCC2099, Pipe, Annulus, or Pressurizer Initial Boron Concentrations

These cards are required only if boron is specified in one of the control words (Word 1) in Cards CCC1201 through CCC1299. The card format is two words per set in sequential expansion format for nv sets. Boron concentrations must be entered for each volume, and zero should be entered for those volumes whose associated control word did not specify boron.

W1(R) Boron concentration (mass of boron per mass of liquid).

W2(I) Volume number.

7.6.27 Card CCC1300, Pipe, Annulus, or Pressurizer Junction Conditions Control Words

This card is optional, and, if missing, velocities are assumed on Cards CCC1301 through CCC1399.

W1(I) Control word. If zero, the first and second words of each set on Cards CCC1301 through CCC1399 are velocities. If one, the first and second words of each set on Cards CCC1301 through CCC1399 are mass flow rates.

7.6.28 Cards CCC1301 through CCC1399, Pipe, Annulus, or Pressurizer Junction Initial Conditions

W1(R) Initial liquid velocity or initial liquid mass flow rate (velocity in m/s, ft/s or mass flow rate in kg/s, lb_m/s), depending on control Word 1 of Card CCC1300.

W2(R) Initial vapor/gas velocity or initial vapor/gas mass flow rate (velocity in m/s, ft/s or mass flow rate in kg/s, lb_m/s), depending on control Word 1 of Card CCC1300.

W3(R) Interface velocity (m/s, ft/s). Enter zero.

W4(I) Junction number.

7.6.29 Cards CCC1401 through CCC1499, Pipe, Annulus, or Pressurizer

Junction Diameter and CCFL Data

These cards are optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to specify only the junction hydraulic diameter for the interphase drag calculation, (i.e., f = 0 in Word 1 of Cards CCC1101 through CCC1199) then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If this card is being used for the CCFL model (i.e., f = 1 in Word 1 of Cards CCC1101 through CCC1199), then enter all four words for the appropriate CCFL model if values different from the default value are desired.

W1(R) Junction hydraulic diameter, D_j (m, ft). This quantity is the junction hydraulic diameter used in the CCFL correlation equation, interphase drag, and form loss Reynolds number. This number must be $\geq$ 0. The number should be computed from $4.0 \bullet \left(\frac{\text{junction area}}{\text{wetted perimeter}}\right)$. If a zero is entered or if the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{junction area}}{\pi}\right)^{0.5}$. See Word 1 of Cards CCC0201 through CCC0299 for the junction area.

W2(R) Flooding correlation form, β. If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be $\geq$ 0 and $\leq$ 1. The default value is 0 (Wallis form). See Section 3 of Volume I for details of the model.

W3(R) Vapor/gas intercept, c. This quantity is the vapor/gas intercept used in the CCFL correlation (when $H_f^{1/2} = 0$) and must be > 0. The default value is 1.

W4(R) Slope, m. This quantity is the slope used in the CCFL correlation and must be > 0. The default value is 1.

W5(I) Junction number.

7.6.30 Card CCC3001 through CCC3099, Pipe, Annulus, or Pressurizer Junction Form Loss Data

These cards are optional. The user-specified form loss coefficients are given in Words 1 and 2 of Cards CCC0901 through CCC0999 if these cards are not entered. If these cards are entered, the form loss coefficients depend on the flow conditions and are calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficients; A_F, A_R, B_F, B_R, C_F, and C_R are user-specified constants. A_F and A_R are Words 1 and 2 of Cards CCC0901 through CCC0999; B_F, B_R, C_F, and C_R are Words 1, 2, 3, and 4 on these cards (CCC3001 through CCC3099); and Re is the Reynolds number based on mixture fluid properties. If these cards are being used for the form loss calculations, then enter all five words for the appropriate expression.

W1(R) B_F ($\geq$ 0). This quantity must be greater than or equal to zero.

W2(R) C_F ($\geq$ 0). This quantity must be greater than or equal to zero.

W3(R) B_R ($\geq$ 0). This quantity must be greater than or equal to zero.

W4(R) C_R ($\geq$ 0). This quantity must be greater than or equal to zero.

W5(I) Junction number.

7.6.31 Cards CCC3101 through CCC3199, Pipe, Annulus, or Pressurizer Volume ORNL ANS Interphase Model Pitch and Span Values

These cards are required if any of the interphase friction flags b in the volume control flags entered on Cards CCC1001 through CCC1099 are set to 2 (ORNL ANS narrow channel model).

W1(R) Pitch (gap, channel width perpendicular to flow), short dimension (m, ft).

W2(R) Span (channel length perpendicular to flow), long dimension (m, ft).

W3(I) Volume number.

7.6.32 Cards CCC3201 through CCC3299, Pipe, Accumulator, or Pressurizer Volume Noncondensable Mass Fractions.

These cards are optional. If omitted, the noncondensable mass fractions are obtained from the noncondensable mass fractions entered on Card 115.

W1-W5(R) Mass fractions for the noncondensable species entered on Card 110. Five quantities must be entered, and zero should be entered for species not present in the volumes. The sum of the noncondensable mass fractions must sum to one within a relative error of $1.0\text{x}10^{-10}$.

W6(I) Volume number.

7.7 Branch, Separator, Jetmixer, Turbine, Feedwater Heater, or ECC

Mixer Component

A branch component is indicated by BRANCH, a steam separator component is indicated by SEPARATR, a jetmixer component is indicated by JETMIXER, a turbine component is indicated by TURBINE, a feedwater heater component is indicated by FWHTR, and an ECC mixer component is indicated by ECCMIX for Word 2 on Card CCC0000. In junction references using the old format, the code for the component inlet is CCC000000 and the code for the component outlet is CCC010000. In the junction references using the expanded format, the connection code is CCCXX000F, where CCC is the component number, XX is the volume number, and F is the face number. More than one junction may be connected to the inlet or outlet. If an end has no junctions, that end is considered a closed end. Normally, only a branch has more than one junction connected to a volume end. Multiple junctions may connect to the ends of pipes and single-volumes, except that a warning message is issued even though the connections are handled correctly. Limiting multiple connections to branch components allows the warning message to indicate probable input error. If more than one junction is connected on one end of a branch, each junction should be modeled as an abrupt area change. For major edits, minor edits, and plot variables, the volume in the branch component is numbered as CCC010000. The junctions associated with the branch component are numbered as CCCMM0000, where MM is the junction number (greater than 00 and less than 10).

A separator (SEPARATR) component is a specialized branch component having three junctions. The number of junctions, nj, defined below, must be three, and no junctions in other components may connect to this component. The variable N defined below must have values of 1, 2, and 3. For the junctions, N = 1 is the vapor/gas outlet, N = 2 is the liquid fall back, and N = 3 is the separator inlet. The <u>from</u> part for the vapor/gas outlet junction must refer to the x-coordinate outlet face of the separator for the old format (CCC010000) or must refer to any of the 6 volume faces of the separator except the x-coordinate inlet face for the expanded format (CCC010002 through CCC010006). The <u>from</u> part for the liquid return junction must refer to the x-coordinate inlet face of the separator for the old format (CCC000000) or must refer to any of the 6 volume faces of the separator except the x-coordinate outlet face for the expanded format (CCC010001, CCC010003 through CCC010006). The separator inlet junction must be connected to the x-coordinate inlet face of the separator for the old format (CCC000000) or must be connected to any of the 6 volume faces of the separator except the x-coordinate outlet face for the expanded format (CCC010001, CCC010003 through CCC010006). To include the direct path from a steam generator downcomer to the steam dome, a bypass volume is recommended. The smooth or abrupt junction option can be used for the three junctions. Appropriate user-input energy loss coefficients may be needed to match a known pressure drop across the separator. We recommend that choking be turned off for all three junctions. The vapor/gas outlet and liquid fall back junctions should use the nonhomogeneous option. The CCFL flag must be turned off (<u>f</u> = 0) for all three junctions. The stratification entrainment/pullthrough flag is not used for separator junctions and should be set to zero (<u>v</u> = 0). The rod bundle interphase friction flag must be turned off (<u>b</u> = 0) in the separator volume. The vertical stratification model flag is not used in the separator volume and should be set to zero (<u>v</u> = 0). The water packing scheme flag is not used in the separator volume and should be set to zero (<u>p</u> = 0).

A jetmixer (JETMIXER) component is a specialized branch component having three junctions numbered in the same manner as the separator. For the junctions, N = 1 represents the drive, N = 2 represents the suction, and N = 3 represents the discharge. The to part of the drive and suction junctions must refer to the inlet end of the jetmixer (old format is CCC000000, and expanded format is CCC010001), and the from part of the discharge junction must refer to the outlet end of the jetmixer (old format is CCC010000, and expanded format is CCC010002). To model a jet pump properly, the junction flow areas of the drive and suction should equal the volume flow area. The CCFL flag must be turned off (f = 0) for all three junctions. The stratification entrainment/pullthrough flag is not used for jetmixer junctions and should be set to zero (v = 0). The rod bundle interphase friction flag must be turned off (b = 0) in the jetmixer volume. The vertical stratification model flag is not used in the jetmixer volume and should be set to zero (v = 0). The water packing scheme flag is not used in the jetmixer volume and should be set to zero (p = 0).

A turbine (TURBINE) component is a specialized branch component having one or two junctions. Additional input is provided to describe the turbine characteristics. A simple turbine might use only one turbine component. A multistage turbine with extraction points or moisture seperator junctions might require several turbine components. The number of junctions, nj, must be equal to 1 or 2. For the junctions, N = 1 is the turbine junction that models the stages, and N = 2 is the extraction (bleed) or moisture seperator junction (optional). The primary vapor/gas inlet junction (N = 1) is a normal junction, and the steam extraction or moisture separator line (N = 2) should be modeled as a crossflow junction. The steam extraction or moisture separator junction (N = 2) must be attached to the 'side' (i.e. on faces 3, 4, 5, or 6 using the expanded format for junction connection codes) of the turbine volume. The turbine junction (N = 1) must be the only entrance junction, and there must be only one exit junction (part of another component). The to part of the vapor/gas inlet junction (N = 1) must refer to the inlet end of the turbine volume (old format is CCC000000, and expanded format is CCC010001). The stratification entrainment/pullthrough flag must be turned off (v = 0). If several turbine components are in series, the choking flag should be left on (c = 0) for the first component but turned off for the other components (c = 1). The smooth junction option (a = 0) should be used at both inlet and outlet junctions. The inlet and outlet junctions must be input as homogeneous junctions (h = 1 or 2). The CCFL flag must be turned off (f = 0) for both junctions. The wall friction must be turned on (f = 0) in the turbine volume in the main flow direction and in the crossflow direction if a steam extraction or moisture seperator junction is specified. The rod bundle interphase friction flag must be turned off (b = 0) in the turbine volume. The vertical stratification model flag is not used in the turbine volume and should be set to zero (v = 0). The water packing scheme flag is not used in the turbine volume and should be set to zero (p = 0). The component volumes immediately upstream and downstream of a turbine component must be singly connected in the main flow direction. That is, if the turbine inlet junction is attached to an 'x' face of the upstream component volume, then that component volume can have only one connection on each of the two 'x' faces of that volume. This restriction is also applicable to the component volume immediately downstream of a turbine component. That is, if the junction attached to the output of a turbine is connected to the 'x' face of the component volume immediately downstream of the turbine, then there can only be one junction connected to each of the two 'x' faces of that component volume. The restriction of single connections is also applicable if the turbine is connected to 'y' or 'z' faces of the attached component volumes.

A feedwater heater (FWHTR) component is a specialized branch component having two or three junctions. It must be defined as horizontally oriented (Word 5 of card CCC0101 must be 0). The number of junctions, nj, defined below, must be two or three, and no junctions in other components may be connected to this component. The variable N, defined below, must have values of 1, 2, or, 3. For the junctions, N = 1 is the vapor inlet, N = 2 is the condensate drain, and N = 3 is the condensate inlet (optional). The to part for the vapor inlet junction must refer to the z-coordinate outlet face of the feedwater heater for the expanded format (CCC010006). The from part for the condensate drain junction must refer to the z-coordinate inlet face of the feedwater heater for the expanded format (CCC010005). A condensate inlet junction can be connected to the x-coordinate inlet or outlet face of the feedwater heater for the old format (CCC000000, CCC010000) or can be connected to any of the 6 volume faces of the feedwater heater for the expanded format (CCC010001 through CCC010006). The smooth or abrupt junction option can be used for the junctions. Appropriate user-input energy loss coefficients may be needed to match a known pressure drop across the feedwater heater. We recommend that choking be turned off for all junctions. All junctions should use the nonhomogeneous option. The CCFL flag must be turned off (f = 0) for all junctions. The stratification entrainment/pullthrough flag is required for all junctions. The flag v should be set to 1 for the vapor inlet junction, indicating an upward oriented junction from a horizontal volume, and set to 2 for the condensate drain junction and the optional condensate inlet junction, indicating they are downward oriented junctions from a horizontal volume. The rod bundle interface friction flag must be turned off (b = 0) in the feedwater heater volume. The vertical stratification model flag is not used in the feedwater heater volume and should be set to zero (v = 0). The water packing scheme flag is not used in the feedwater heater volume and should be set to zero (p = 0).

An ECC mixer (ECCMIX) component is a specialized branch component that requires three junctions with a certain numbering order. The physical extent of the ECC mixer is a length of the cold leg, or any other horizontal pipe, centered around the position of the ECC injection location. The length of this pipe segment should be equal to three times the inside diameter of the pipe (if the physical arrangement of the system permits). Junction number one (N = 1, the lowest numbered junction) must be the ECC connection. This is, in some respects, similar to the drive junction of a jetmixer component. Junction number two (N = 2, the junction with higher number than the first one) should be the one that is the flow inlet to this component in normal operation. The geometrical angle between the axis of junctions one and two is one of the necessary inputs, as will be specified later. The third, or discharge, junction (N = 3) is the normal outlet of flow through this pipe segment. The to part of junctions one and two must refer to the inlet end of the ECC mixer (old format is CCC000000, and expanded format is CCC010001), and the from part of the discharge junction must refer to the outlet end of the ECC mixer (old format is CCC010000, and expanded format is CCC010002). Two or more ECC mixer components may be considered in modeling some piping. These may be connected in tandem and require at least one normal volume between them.

7.7.1 Card CCC0001, Branch, Separator, Jetmixer, Turbine, Feedwater Heater, or ECC Mixer Information

This card is required for branch, separator, jetmixer, turbine, feedwater heater, or ECC mixer components.

W1(I) Number of junctions, nj. The variable nj is the number of junctions described in the input data for this component and must be equal to or greater than zero and less than ten. This number must be 3 for SEPARATR, JETMIXER, and ECCMIX components; must be 1 or 2 for TURBINE components; and must be 2 or 3 for FWHTR components. For BRANCH components, not all junctions connecting to the branch need be described with this component input, and nj is not necessarily the total number of junctions connecting to the branch. Junctions described in single-junctions, time-dependent junctions, pumps, separators, jetmixers, feedwater heaters, ECC mixers, and other branches can be connected to this branch.

W2(I) Initial condition control. This word is optional and, if missing, the junction initial velocities in the first and second words on Card CCCN201 are assumed to be velocities. If zero, velocities are assumed; if one, mass flow rates are assumed.

7.7.2 Card CCC0002, Separator Component Options

If this card is missing, the simple separator is used.

This card is optional for a separator component. It is not allowed for branch, jetmixer, turbine, or ECC mixer components. The first word specifies the separator option while the second word specifies the number of actual separator components represented by this ATHENA SEPARATR component. The second word is needed if the user uses the General Electric separator options

W1(I) Separator option, ISEPST. A value of 0 specifies the simple separator contained in previous versions of ATHENA (default), a value of 1 specifies the General Electric dryer model, a value of 2 specifies a General Electric two-stage separator, and a value of 3 specifies a General Electric three-stage separator.

W2(I) Number of separator components represented by this ATHENA component. The number is needed only if Word 1 has a value of two or three.

7.7.3 Card CCC0003, Feedwater Heater Data

This card is optional for the feedwater heater component. It is not allowed for branch, seperator, jetmixer, turbine, or ECC mixer components. Word 1 is the number of a table that specifies the relationship between the non-dimensional water level and the void on the shell side of the feedwater heater. The non-dimensional water level is equal to the water level divided by the shell diameter, The table must be a REAC-T type table, which has no units conversion. If this card is missing, the code uses the liquid volume fraction (1 - void) as the default value for the non-dimensional water level.

W1(I) Table number specifying non-dimensional water level for the table function value (Cards 202TTT01-202TTT99, Word 2) versus void for the table argument value (Cards 202TTT01-202TTT99, Word 1) in the shell side of the feedwater heater.

7.7.4 Cards CCC0101 through CCC0109, Branch, Separator, Jetmixer, Turbine, Feedwater Heater, or ECC Mixer X-Coordinate Volume Data

This card (or cards) is required for branch, separator, jetmixer, turbine, feedwater heater, and ECC mixer components. The words can be entered on one or more cards, and the card numbers need not be consecutive.

W1(R) Volume flow area in the x-direction (m^2, ft^2).

W2(R) Length of volume in the x-direction (m, ft).

W3(R) Volume of volume (m^3, ft^3). The code requires that the volume equals the volume flow area times the length (W3 = W1•W2). This is required for all three directions. At least two of the three quantities, W1, W2, and W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the words are zero, the volume must equal the x-direction area times the x-direction length within a relative error of 0.000001. The same relative error check is done for the y- and z-directions.

W4(R) Azimuthal (horizontal) angle (degrees). The absolute value of this angle must be ≤ 360 degrees and is defined as a positional quantity. This angle is in the horizontal x-y plane. The angle 0 degrees is on the x axis, and the angle 90 degrees in on the y axis. Positive angles are rotated from the x axis toward the y axis. This quantity is not used in the calculation but is specified for automated drawing of nodalization diagrams.

W5(R) Inclination (vertical) angle (degrees). The absolute value of this angle must be ≤ 90 degrees. The angle 0 degrees is horizontal; positive angles have an upward inclination, i.e., the inlet is at the lowest elevation. This angle is used in the flow regime determination, in the interphase drag calculation, and for automated drawing of nodalization diagrams. When the absolute value of the inclination (vertical) angle is less than or equal to 30 degrees, the horizontal flow regime map is used. When the absolute value of the inclination (vertical) angle is greater than or equal to 60 degrees, the vertical flow regime map is used. Between 30 and 60 degrees, interpolation is used. For an ECCMIX component, this angle is not used to decide if the horizontal or vertical flow regime map is used. Rather, the ECC mixer flow regime map is used. For an ECCMIX component, the absolute value of this inclination angle must be ≤ 15 degrees. Any other value will be considered an input error.

W6(R) Elevation change (m, ft). A positive value is an increase in elevation. The absolute value of this quantity must be less than or equal to the volume length. If the inclination (vertical) angle is zero, this quantity must be zero. If the inclination (vertical) angle is nonzero, this quantity must also be nonzero and have the same sign. The elevation change is used in the gravity head and in checking loop closure. See Section 2.4.1 of Volume II of the manual for further discussion.A calculated elevation angle is determined by the arcsin of the ratio of the elevation change (this word) and the volume length (Word 2). This calculated elevation angle is used in the additional stratified force term.

W7(R) Wall roughness in the x-direction (m, ft). The x-direction wall roughness is limited to be greater than or equal to 1.0×10^{-9} times the x-direction hydraulic diameter. If zero, the x-direction wall roughness is computed from 1.0×10^{-9} times the x-direction hydraulic diameter.

W8(R) Hydraulic diameter in the x-direction (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{x-direction volume flow area}}{\text{x-direction wetted perimeter}}\right)$. If zero, the x-direction hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{x-direction volume flow area}}{\pi}\right)^{0.5}$. A check is made that the x-direction wall roughness is less than half the x-direction hydraulic diameter. See Word 1 for the x-direction volume flow area.

W9(I) Volume control flags. This word has the packed format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scalar oriented and coordinate direction oriented flags. Only one value for a scalar oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. This word enters the scalar oriented flags and the x-coordinate flag.

The digit t specifies whether the thermal front tracking model is to be used; t = 0 specifies that the front tracking model is not to be used for the volume, and t = 1 specifies that the front tracking model is to be used for the volume. The thermal front tracking model can only be applied to vertically oriented components. This model is not used for SEPARATR, JETMIXER, TURBINE, FWHTR, or ECCMIX components, and the flag if entered as 1 is considered an input error.

The digit l specifies whether the mixture level tracking model is to be used; l = 0 specifies that the level model not be used for the volume, and l = 1 specifies that the level model be used for the volume. The mixture level tracking model can only be applied to vertically oriented components. This model is not used for SEPARATR, JETMIXER, TURBINE, FWHTR, or ECCMIX components, and the flag if entered as 1 is considered an input error.

The digit p specifies whether the water packing scheme is to be used; p = 0 specifies that the water packing scheme is to be used for the volume, and p = 1 specifies that the water packing scheme is not to be used for the volume. The water packing scheme is recommended when modeling a pressurizer. The water packing scheme is only applied to vertically oriented volumes. This digit is used for the BRANCH and ECCMIX components. For the SEPARATR, JETMIXER, FWHTR, and TURBINE components, the water packer scheme is not allowed, the digit is not used and may be input as 0 or 1. The major edit will show p = 1.

The digit v specifies whether the vertical stratification model is to be used; v = 0 specifies that the vertical stratification model is to be used for the volume, and v = 1 specifies that the vertical stratification model is not to be used for the volume. The vertical stratification model is recommended when modeling a pressurizer. The vertical stratification model is only applied to vertically oriented volumes. This digit is used for the BRANCH component. For the SEPARATR, JETMIXER, TURBINE, FWHTR, and ECCMIX components, the vertical stratification model is not allowed, the digit is not used and may be input as 0 or 1. The major edit will show v = 1.

The digit b specifies the interphase friction that is used; b = 0 specifies that the pipe interphase friction model will be applied, b = 1 specifies that the rod bundle interphase friction model will be applied, and b = 2 specifies that the ORNL ANS narrow channel model will be applied (Card CCC0111 required). The b = 1 option and the b = 2 option are only applied to vertically oriented volumes. This digit is only used for the BRANCH component. For the SEPARATR, JETMIXER, TURBINE, FWHTR, and ECCMIX components, the rod bundle interphase friction and the ORNL ANS narrow channel model are not allowed; the digit is not used and must be input as 0.

The digit f specifies whether wall friction is to be computed; f = 0 specifies that wall friction effects are to be computed along the x-coordinate direction of the volume, and f = 1 specifies that wall friction effects are not to be computed along the x-coordinate for the volume. For a SEPARATR component, either 0 or 1 may be entered; the code will set f = 1 and no wall friction will be calculated. The digit f must be entered as 1 for a TURBINE component.

The digit e specifies if nonequilibrium or equilibrium is to be used; e = 0 specifies that a nonequilibrium (unequal temperature) calculation is to be used, and e = 1 specifies that an equilibrium (equal temperature) calculation is to be used. Equilibrium volumes should not be connected to nonequilibrium volumes. The equilibrium option is provided only for comparison to other codes.

7.7.5 Cards CCC0181 through CCC0189, Branch, Separator, Jetmixer, Turbine, Feedwater Heater, or ECC Mixer Y-Coordinate Volume Data

These cards are optional for BRANCH, SEPARATR, JETMIXER, TURBINE, and ECCMIX components. These cards are used when the user specifies the y-direction connection with the crossflow model. The volume of the volume is the same for the x-, y-, and z-directions. If these cards are entered, either W1 or W2 must be nonzero.

W1(R) Area of the volume in the y-direction (m^2, ft^2). If these cards are missing or if this word is zero, this y-direction volume flow area is computed from $\frac{\text{volume of volume}}{\text{y-direction length}}$.

W2(R) Length of the crossflow volume in the y-direction (m, ft). If these cards are missing, this y-direction length is computed from $2.0 \bullet \left(\frac{\text{x} - \text{direction volume flow area}}{\pi}\right)^{0.5}$. If this word is zero, this y-direction length is computed from $\frac{\text{volume of volume}}{\text{y-direction volume flow area}}$.

W3(R) Wall roughness in the y-direction (m, ft). The y-direction wall roughness is limited to be greater than or equal to $1.0\text{x}10^{-9}$ times the y-direction hydraulic diameter. If zero, the y-direction wall roughness is computed from $1.0\text{x}10^{-9}$ times the y-direction hydraulic diameter.

W4(R) Hydraulic diameter in the y-direction (m, ft). If these cards are missing or if this word is zero, this y-direction hydraulic diameter is computed from $4.0 \bullet \left(\frac{\text{y} - \text{direction volume flow area}}{\pi \bullet \text{x} - \text{direction volume flow area}}\right)^{0.5}$. See Section 2.4 of this volume of the manual. A check is made to ensure the y-direction wall roughness is less than half the y-direction hydraulic diameter.

W5(I) Volume control flags. This word has the general packed format tlpvbfe, but this word is limited to 00000f0 since it only enters the coordinate oriented flags for the y-direction.

The digit f specifies whether wall friction is to be computed; f = 0 specifies that wall friction effects are to be computed along the y-coordinate direction of the volume, and f = 1 specifies that wall friction effects are not to be computed along the y-coordinate direction of the volume. For a SEPARATR component, either 0 or 1 may be entered; the code will set f = 1 and no wall friction will be calculated. The digit f must be entered as 1 for a turbine component.

W6(R)

W7(R)

W8(R) This word is the position change in the fixed z (vertical) direction as the flow passes from the y inlet face to the y outlet face (m, ft). This quantity affects problems if connections are made to the y faces.

7.7.6 Cards CCC0191 through CCC0199, Branch, Separator, Jetmixer, Turbine, Feedwater

Heater, or ECC Mixer Z-Coordinate Volume Data

These cards are optional for BRANCH, SEPARATR, JETMIXER, TURBINE, FWHTR, and ECCMIX components. These cards are used when the user specifies the z-direction connection with the crossflow model. The volume of the volume is the same for the x-, y-, and z-directions. If these cards are entered, either W1 or W2 must be nonzero.

W1(R) Area of the volume in the z-direction (m^2, ft^2). If these cards are missing or if this word is zero, this z-direction volume flow area is computed from $\frac{\text{volume of volume}}{\text{z-direction length}}$.

W2(R) Length of the crossflow volume in the z-direction (m, ft). If these cards are missing, this z-direction length is computed from $2.0 \bullet \left(\frac{\text{x – direction volume flow area}}{\pi}\right)^{0.5}$. If this word is zero, this z-direction length is computed from $\frac{\text{volume of volume}}{\text{z-direction volume flow area}}$.

W3(R) Wall roughness in the z-direction (m, ft). The z-direction wall roughness is limited to be greater than or equal to 1.0×10^{-9} times the z-direction hydraulic diameter. If zero, the z-direction wall roughness is computed from 1.0×10^{-9} times the z-direction hydraulic diameter.

W4(R) Hydraulic diameter in the z-direction (m, ft). If these cards are missing or if this word is zero, this z-direction hydraulic diameter is computed from $4.0 \bullet \left(\frac{\text{z – direction volume flow area}}{\pi \bullet \text{x – direction volume flow area}}\right)^{0.5}$. See Section 2.4 of this volume of the manual. A check is made to ensure the z-direction wall roughness is less than half the z-direction hydraulic diameter.

W5(I) Volume control flags. This word has the general packed format tlpvbfe, but this word is limited to 00000f0 since it only enters the coordinate oriented flags for the z-direction.

The digit f specifies whether wall friction is to be computed; f = 0 specifies that wall friction effects are to be computed along the z-coordinate direction of the volume, and f = 1 specifies that wall friction effects are not to be computed along the z-coordinate direction of the volume. For a SEPARATR component, either 0 or 1 may be entered; the code will set f = 1 and no wall friction will be calculated. The digit f must be entered as 1 for a turbine component.

W6(R)

W7(R)

W8(R) This word is the position change in the fixed z (vertical) direction as flow passes from the z inlet face to the z outlet face (m, ft). This quantity affects problems if connections are made to the z faces.

7.7.7 Card CCC0111, Branch, Separator, Jetmixer, Turbine, Feedwater Heater, or ECC Mixer ORNL ANS Interphase Model Pitch and Span Values

This card is required if the interphase friction flag b in Word 9 of Card CCC0101 through CCC0109 is set to 2 (ORNL ANS narrow channel model), which is allowed for a BRANCH component. It is not allowed for SEPARATR, JETMIXER, TURBINE, FWHTR, and ECCMIX components.

W1(R) Pitch (gap, channel width perpendicular to flow), short dimension (m, ft).

W2(R) Span (channel length perpendicular to flow), long dimension (m, ft)

7.7.8 Card CCC0131, Branch, Separator, Jetmixer, Feedwater Heater, or ECC Mixer Additional Wall Friction

This card is optional for the BRANCH, SEPARATR, JETMIXER, FWHTR, and ECCMIX components, and it is not allowed for a TURBINE component. If this card is not entered, the default values are 1.0 for the laminar shape factor and 0.0 for the viscosity ratio exponent. Two, four, or six quantities may be entered on the card, and the data not entered are set to default values. A description of this input is presented in Section 3 of Volume I.

W1(R) Shape factor for coordinate direction 1.

W2(R) Viscosity ratio exponent for coordinate direction 1.

W3(R) Shape factor for coordinate direction 2.

W4(R) Viscosity ratio exponent for coordinate direction 2.

W5(R) Shape factor for coordinate direction 3.

W6(R) Viscosity ratio exponent for z-coordinate direction 3.

7.7.9 Card CCC0141, Branch, Separator, Jetmixer, Feedwater Heater, or ECC Mixer Alternate Turbulent Wall Friction

This card is optional for the BRANCH, SEPARATR, JETMIXER, FWHTR, and ECCMIX components, and it is not allowed for a TURBINE component. This card allows the specification of a user defined turbulent friction factor for each coordinate direction. The turbulent friction factor has the form $f = A + B(Re)^{-C}$ where A, B, and C are entered for each coordinate of each volume. If this cards is not entered, the standard turbulent friction factor is used for all coordinates. If the card is entered, the standard turbulent friction factor can be selected for a particular coordinate direction by entering zeros for the three quantities. Three, six, or nine quantities may be entered on the card, and the data not entered are set to zeros.

W1(R) A for coordinate direction 1.

W2(R) B for coordinate direction 1

W3(R) C for coordinate direction 1.

W4(R) A for coordinate direction 2.

W5(R) B for coordinate direction 2.

W6(R) C for coordinate direction 2.

W7(R) A for coordinate direction 3.

W8(R) B for coordinate direction 3.

W9(R) C for coordinate direction 3.

7.7.10 Card CCC0200, Branch, Separator, Jetmixer, Turbine, Feedwater Heater, or ECC Mixer Volume Initial Conditions

This card is required for the BRANCH, SEPARATR, JETMIXER, TURBINE, FWHTR, and ECCMIX components.

W1(I) Control word. This word has the packed format $\underline{\varepsilon bt}$. It is not necessary to input leading zeros.

The digit $\underline{\varepsilon}$ specifies the fluid, where $\underline{\varepsilon}$ = 0 is the default fluid. The value for $\underline{\varepsilon}$ > 0 corresponds to the position number of the fluid type indicated on the 120 - 129 cards (i.e., $\underline{\varepsilon}$ = 1 specifies H_2O, $\underline{\varepsilon}$ = 2 specifies D_2O, etc.). The default fluid is that set for the hydrodynamic system by Cards 120 through 129 or this control word in another volume in this hydrodynamic system. The fluid type set on Cards 120 through 129 or these control words must be consistent (i.e., not specify different fluids). If Cards 120 through 129 are not entered and all control words use the default $\underline{\varepsilon}$ = 0, then H_2O is assumed to be the fluid.

The digit $\underline{b}$ specifies whether boron is present or not. The digit $\underline{b}$ = 0 specifies that the volume liquid does not contain boron, and $\underline{b}$ = 1 specifies that a boron concentration in mass of boron per mass of liquid (which may be zero) is being entered after the other required thermodynamic information.

The digit t specifies how the following words are to be used to determine the initial thermodynamic state. Entering t equal to 0 through 3 specifies one component (vapor/liquid). Entering t equal to 4, 5, 6, or 8 allows the specification of two components (vapor/liquid and noncondensable gas).

With options t equal to 4, 5, 6, or 8, the names of the components of the noncondensable gas must be entered on Card 110, and the mass fractions of the components of the noncondensable gas are entered on Card 115. Card CCC0701 may also be used for the mass fractions of the components on the noncondensable gas.

If t = 0, the next four words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor/gas specific internal energy (J/kg, Btu/lb_m), and vapor/gas void fraction. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the specific internal energies used to define the thermodynamic state. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 1, the next two words are interpreted as temperature (K, ^{o}F) and static quality in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 2, the next two words are interpreted as pressure (Pa, lb_f/in^2) and static quality in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^{o}F) in nonequilibrium or equilibrium conditions depending on the pressure and temperature used to define the thermodynamic state. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

The following options are used for input of noncondensable states. In all cases, the criteria used for determining the range of values for static quality are;

1. 1.0E-9 $\leq$ static quality $\leq$ 0.99999999, two phase conditions

2. static quality < 1.0E-9 or static quality > 0.99999999, single-phase conditions.

The static quality is given by $M_g/(M_g + M_f)$, where $M_g = M_s + M_n$. Section 3.2 of Volume I of the manual discusses this further.

Noncondensable options are as follows:

If t = 4, the next three words are interpreted as pressure (Pa, $lb_f/in.^2$), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static quality greater than 0.0 and less than or equal to 1.0, saturated noncondensables (100% relative humidity) will result. The temperature is restricted to be less than the saturation temperature at the input pressure and less than the critical temperature; otherwise, an input error will occur. Setting static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable, 0% relative humidity) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 5, the next three words are interpreted as temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. Both the static and noncondensable qualities are restricted to be between 1.0E-9 and 0.99999999. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions. Little experience has been obtained using this option, and it has not been checked out.

If t = 6, the next five words are interpreted as pressure (Pa, $lb_f/in.^2$), liquid specific internal energy (J/kg, Btu/lb_m), vapor/gas specific internal energy (J/kg, Btu/lb_m), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the specific internal energies used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing (t = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume temperature is calculated from the noncondensable energy equation using the input vapor/gas specific internal energy. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions

. If t = 8, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid temperature (K, ^oF), vapor/gas temperature (K, ^oF), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the temperatures used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume specific internal energy is calculated from the noncondensable energy equation using the input vapor/gas temperature. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

W2-W7(R) Quantities as described under Word 1. Depending on the control word, two through five thermodynamic quantities may be required. Enter only the minimum number required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

7.7.11 Cards CCCN101 through CCCN109, Branch, Separator, Jetmixer, Turbine, Feedwater Heater, or ECC Mixer Junction Geometry

These cards are required if nj (Card CCC0001, Word 1) is greater than zero. Cards with N equal to 1 through 9 are entered, one for each junction. The variable N equal to 1, 2, and 3 must be used for SEPARATR, JETMIXER, and ECCMIX components. The variable N equal to 1 must be used for TURBINE components and may be equal to 1 or 2. The variable N equal to 1 and 2 must be used for FWHTR components and may be equal to 1, 2, or 3. For a BRANCH component, N need not be consecutive, but nj cards must be entered. The card format for Words 1 through 6 is listed below and is identical to Words 1 through 6 on Card CCC0101 of the Single-Junction Geometry Card, except that N instead of 0 is used in the fourth digit. There are special requirements for Words 1 and 2 that are indicated in the introductory paragraphs to Section 7.7. Word 7 is not used for JETMIXER and TURBINE components. Word 7 is defined for SEPARATR and ECCMIX components. Words 7, 8, and 9 are defined for BRANCH and FWHTR components.

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. An old or an expanded format can be used to connect volumes. In the old format (only allowed for connection to 1-D components), use CCC000000 if the connection is to the inlet side of the component and use CCC010000 if the connection is to the outlet side of the component. In the expanded format, the connection code for 1-D components is CCCXX000F [where CCC is the component number, XX is the volume number (greater than 00 and less than 100) for pipes/annuli/pressurizers, XX is 01 for all other 1-D components, and F indicates the face number]. A nonzero F specifies the expanded format. The number F equal to 1 and 2 specifies the inlet and outlet faces for the first coordinate direction (x or r), which is a 1-D volume's coordinate direction (x) (see Section 2.1 of Volume II of this manual). The number F equal to 3 through 6 specifies crossflow (y or z) for 1-D volumes. The number F equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction (y or θ); F equal to 5 and 6 would do the same for the third coordinate direction (z). For connecting to a time-dependent volume using the old format, both CCC000000 and CCC010000 are allowed. For connecting to a time-dependent volume using the expanded format, only the number F equal to 1 or 2 is allowed. Section 4.4 in this Appendix discusses this further.

W2(I) To connection code to a component. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.

W3(R) Junction area (m^2, ft^2). If zero, the area is set to the minimum volume area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or smaller than the minimum of the adjoining volume areas. For smooth area changes, there are no restrictions.

W4(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or zero. A variable loss coefficient may be specified (see Section 7.7.13 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W5(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. A variable loss coefficient may be specified (see Section 7.7.13 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W6(I) Junction control flags. This word has the packed format jefvcahs.

The digit j is not used and should be input as zero (j = 0). The jet junction model is not used.

The digit e specifies the modified PV term in the energy equations; e = 0 specifies that the modified PV term will not be applied, and e = 1 specifies that the modified PV term will be applied. This digit is only for the BRANCH component. For the SEPARATR, JETMIXER, TURBINE, FWHTR, and ECCMIX components, this digit is not used and should be set to 0. The major edit output will show e = 0.

The digit f specifies CCFL options; f = 0 specifies that the CCFL model will not be applied, and f = 1 specifies that the CCFL model will be applied. This digit is only used for the BRANCH component. For the SEPARATR, JETMIXER, TURBINE, FWHTR, and ECCMIX components, the CCFL model is not allowed, this digit is not used and should be set to 0. The major edit output will show f = 0.

The digit v specifies stratification entrainment/pullthrough options, where this model is for junctions connected to a horizontal or vertical volume; v = 0 specifies the model is not applied, v = 1 specifies an upward oriented junction from a horizontal volume (offtake volume must be vertical), v = 2 specifies a downward oriented junction from a horizontal volume (offtake volume must be vertical), and v = 3 specifies a centrally (side) located junction from a horizontal or vertical volume. For v = 1 or 2, the horizontal volume flow area must be greater than or equal to the offtake volume flow area. This digit is only used for the BRANCH and FWHTR components. For FWHTR components, this digit must be 1 for the vapor inlet junction (N = 1) and 2 for the condensate drain junction (N = 2) and condensate inlet junction(N = 3). For the SEPARATR, JETMIXER, TURBINE, and ECCMIX components, the stratification entrainment/pullthrough model is not allowed, this digit is not used and should be set to 0.

The digit c specifies choking options; c = 0 specifies that the choking model will be applied, and c = 1 specifies that the choking model will not be applied.

The digit a specifies area change options; a = 0 specifies either a smooth area change or no area change, a = 1 specifies full abrupt area change model (code-calculated K_{loss}, area apportioning at a branch, restricted junction area, and extra interphase drag), and a = 2 specifies a partial abrupt area change (no code-calculated K_{loss}, but includes area apportioning at a branch, restricted junction area, and extra interphase drag). It is recommended that the abrupt area change model (a = 1 or a = 2) be used at branches.

The digit h specifies nonhomogeneous or homogeneous; h = 0 specifies the nonhomogeneous (two-velocity momentum equations) option, and h = 1 or 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 1 or 2), the major edit printout will show h = 1.

The digit s specifies momentum flux options. This digit is used for the BRANCH, SEPARATR, and FWHTR components; s = 0 specifies momentum flux in both the to and the from volume, s = 1 specifies momentum flux in the from volume but not in the to volume, s = 2 specifies momentum flux in the to volume but not in the from volume, and s = 3 specifies no momentum flux in either the to volume or the from volume. For the JETMIXER, TURBINE, and ECCMIX components, this digit is not used and should be input as 0.

W7(R) Volume fraction limit (for SEPARATR), angle (for ECCMIX), and subcooled discharge coefficient (for BRANCH and FWHTR). This word is optional only for a SEPARATR, an ECCMIX, a FWHTR, or a BRANCH. It is not used for a JETMIXER or a TURBINE.

For SEPARATR, this word is volume fraction limit. This is only used for the simple separator. For the vapor/gas outlet junction (N = 1), this quantity (VOVER) is the vapor/gas volume fraction above which flow out of the vapor/gas outlet junction has a vapor/gas volume fraction of VGMAX (input cards CCCN901-CCCN909 or default 1.0). If the word is missing, a default value of 0.5 is used. For the liquid fall back junction (N = 2), this quantity (VUNDER) is the liquid volume fraction above which flow out of the liquid fall back junction has a liquid volume fraction of VFMAX (input cards CCCN901-CCCN909 or default 1.0). If the word is missing, a default value of 0.15 is used. For the separator inlet junction (N = 3), this word is not used.

For ECCMIX, this word is angle and is the angle between the axis of the ECC injection line and the main pipe (or the angle between Junctions 1 and 2). This angle must be between 0 and 180 degrees. If missing, a 90-degree connection for the ECC pipe is assumed.

For BRANCH and FWHTR, this word is subcooled discharge coefficient. This quantity is applied only to subcooled choked flow calculations. The quantity must be > 0 and $\leq$ 2.0. If W7, W8, and W9 are missing, then W7, W8, and W9 are set to 1.0.

W8(R) For BRANCH and FWHTR, this optional word is two-phase discharge coefficient. This word is not used for JETMIXER, TURBINE, ECCMIX, or SEPATATR. This quantity is applied only to two-phase choked flow calculations. The quantity must be > 0 and $\leq$ 2.0. If W7 is entered and W8 and W9 are missing, then W8 and W9 are set to 1.0.

W9(R) For BRANCH and FWHTR, this optional word is superheated discharge coefficient. This word is not used for JETMIXER, TURBINE, ECCMIX, or SEPATATR. This quantity is applied only to superheated choked flow calculations. The quantity must be > 0 and $\leq$ 2.0. If W7 and W8 are entered and W9 is missing, then W9 is set to 1.0.

7.7.12 Cards CCCN110, Branch, Separator, Jetmixer, Turbine, Feedwater Heater, or ECC

Mixer Junction Diameter and CCFL Data

These cards are optional for the BRANCH, SEPARATR, JETMIXER, FWHTR, and ECCMIX components, and they are not allowed for the TURBINE component. The value N should follow the same approach as used in Cards CCCN101 through CCCN109. The defaults indicated for each word are used if the card is not entered. If these cards are being used to specify only the junction hydraulic diameter for the interphase drag calculations (i.e., $\underline{f}$ = 0 in Word 6 of Cards CCCN101 through CCCN109), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If these cards are being used for the CCFL model (i.e., $\underline{f}$ = 1 in Word 6 of Cards CCCN101 through CCCN109), then enter all four words for the appropriate CCFL model if values different from the default values are desired.

W1(R) Junction hydraulic diameter, D_j (m, ft). This quantity is the junction hydraulic diameter used in the CCFL correlation equation, interphase drag, and form loss Reynolds number. This number must be $\geq$ 0. This number should be computed from $4.0 \bullet \left(\frac{\text{junction area}}{\text{wetted perimeter}}\right)^{0.5}$. If a zero is entered or if the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{junction area}}{\pi}\right)^{0.5}$ of the respective junction. See Word 3 of Cards CCCN101 through CCCN109 for the junction area. For a TURBINE component, the default is used.

W2(R) Flooding correlation form, β. If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be $\geq$ 0 and $\leq$ 1. The default value is 0 (Wallis form). See Section 3 of Volume I for details of the model. This is only used for the BRANCH component.

W3(R) Vapor/gas intercept, c. This quantity is the vapor/gas intercept used in the CCFL correlation (when $H_f^{1/2} = 0$) and must be > 0. The default value is 1. This is only used for the BRANCH component.

W4(R) Slope, m. This quantity is the slope used in the CCFL correlation and must be > 0. The default value is 1. This is only used for the BRANCH component.

7.7.13 Cards CCCN112, Branch, Separator, Jetmixer, Turbine, Feedwater Heater, or ECC Mixer Junction Form Loss Data

These cards are optional for the BRANCH, SEPARATR, JETMIXER, TURBINE, FWHTR, and ECCMIX components. The value of N should follow the same approach as used in Cards CCCN101 through CCCN109. The user-specified form loss coefficients are given in Words 4 and 5 of Cards

CCCN101 through CCCN109 if these cards are not entered. If these cards are entered, the form loss coefficients depend on the flow conditions and are calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficients; A_F, A_R, B_F, B_R, C_F, and C_R are user-specified constants. A_F and A_R are Words 4 and 5 of Cards CCCN101 through CCCN109; B_F, B_R, C_F, and C_R are Words 1, 2, 3, and 4 on these cards (CCCN112); and Re is the Reynolds number based on mixture fluid properties. If these cards are being used for the form loss calculation, then enter all four words for the appropriate expression.

W1(R) B_F ($\geq$ 0). This quantity must be greater than or equal to zero.

W2(R) C_F ($\geq$ 0). This quantity must be greater than or equal to zero.

W3(R) B_R ($\geq$ 0). This quantity must be greater than or equal to zero.

W4(R) C_R ($\geq$ 0). This quantity must be greater than or equal to zero.

7.7.14 Card CCCN113, Branch, Separator, Jetmixer, Turbine, Feedwater Heater, or ECC Mixer Junction Face Placement Data

These cards are optional for the BRANCH, SEPARATR, JETMIXER, FWHTR, and ECCMIX components, and they are not allowed for a TURBINE component. It is used to improve the graphical display of the hydrodynamic nodes. It is used to resolve problems with converging and diverging flows, that is, multiple junctions attached to the same face of a volume. With the standard input, each junction attached to the same face of a volume would be superimposed on the graphical display since each junction would be attached to the center of the volume face. For junctions with this card, the point of leaving the “from” volume and entering the “to” volume is allowed to be other than the center of the faces. The volume face is perpendicular to one of the coordinate directions. The attachment position is given by specifying the coordinates on the remaining two directions. Four words are entered on the card; two words for the coordinates for the “from” face, and two words for the two coordinates for the “to” face. The coordinates are entered in the order x, then y, then z, skipping the coordinate direction perpendicular to the face. The values are dimensionless. The actual coordinates are given by these values times the position change in moving from the volume center to the face in that direction. A value of 0.0 means no change from the center of the volume in that direction, and 1.0 means move to the edge of the volume in that direction. Positive or negative numbers can be entered, and the sign indicates moving in the positive or negative direction along that coordinate. A value greater than 1.0 can be used to get separation; the maximum allowed value is 25.0. The default is 0.0.

W1(R) First remaining coordinate value for the “from” face (dimensionless).

W2(R) Second remaining coordinate value for the “from” face (dimensionless).

W3(R) First remaining coordinate value for the “to” face (dimensionless).

W4(R) Second remaining coordinate value for the “to” face (dimensionless).

7.7.15 Cards CCCN201, Branch, Separator, Jetmixer, Turbine, Feedwater Heater, or ECC Mixer Junction Initial Conditions

These cards are required depending on the value of nj as described for Cards CCCN101 through CCCN109. The values of N should follow the same approach as used in Cards CCCN101 through CCCN109. A 90% extraction limit during input processing is tested for the vapor/gas at the separator vapor/gas outlet junction and for the liquid at the separator liquid fall back junction. If greater than 90%, an input error occurs.

W1(R) Initial liquid velocity or initial liquid mass flow rate (velocity in m/s, ft/s or mass flow rate in kg/s, lb_m/s), depending on control Word 2 of Card CCC0001.

W2(R) Initial vapor/gas velocity or initial vapor/gas mass flow rate (velocity in m/s, ft/s or mass flow rate in kg/s, lb_m/s), depending on control Word 2 of Card CCC0001.

W3(R) Interface velocity (m/s, ft/s). Enter zero.

7.7.16 Card CCC0300, Turbine/Shaft Geometry

If a TURBINE component is specified, the following words are used (this card is required for TURBINE components):

W1(R) Turbine stage shaft speed, ω (rad/s, rev/min). This speed should equal the shaft speed used in the SHAFT component.

W2(R) Inertia of rotating stages in stage group, I_{tn} ($kg \cdot m^2$, $lb_m \cdot ft^2$).

W3(R) Shaft friction coefficient f_i, ($N \cdot m \cdot s$, $lb_f \cdot ft \cdot s$). The term equals $f_i\omega$ is used in the frictional torque equation. The frictional torque is used by the SHAFT component.

W4(I) Shaft component number to which the turbine stage is connected.

W5(R) Disconnect trip number. If zero, the turbine is always connected to the shaft, If nonzero, the turbine is connected to the shaft when the trip is false and disconnected when the trip is true.

W6(R) Moisture separator efficiency. Omit this word if there is no second junction for the turbine. Input of this word when there is no second junction will cause an informative message to be printed. If zero, signifies that the second turbine junction is a steam extraction junction and if greater than zero, signifies that the second turbine junction is a moisture separator junction. This parameter is optional, has a default value of zero, and has a maximum value of one.

7.7.17 Card CCC0302, Turbine/Shaft Variable Frictional Torque

This card is used only for TURBINE components and is optional. If this card is not entered, the frictional torque equals $f_i\omega$, where f_i is obtained from Word 3 of Card CCC0300. If this card is entered, the frictional torque is computed from

$$\tau_{fr} = \pm\left(\tau_{fr0} + \tau_{fr1}\left|\frac{\omega}{\omega_R}\right|^{x1} + \tau_{fr2}\left|\frac{\omega}{\omega_R}\right|^{x2} + \tau_{fr3}\left|\frac{\omega}{\omega_R}\right|^{x3} + f_i\omega\right)$$

where ω is the turbine speed and ω_R is the rated speed of the turbine and is obtained from Card CCC0400. The turbine frictional torque is negative if $\frac{\omega}{\omega_R} > 0$, and it is positive if $\frac{\omega}{\omega_R} < 0$. Fewer than seven words may be entered. Entering a total of one word, three words, five words, or seven words in allowed. Entering a total of two words, four words, or six words is not allowed. The default values are 0.0 for the coefficients.

W1(R) Constant frictional torque coefficient, τ_{fr0} (N-m, lb_f-ft).

W2(R) First frictional torque coefficient, τ_{fr1} (N-m, lb_f-ft).

W3(R) First exponent, x1. This is used on the speed ratio used with the frictional torque coefficient τ_{fr1}. If not entered, a default value of 1.0 is used.

W4(R) Second frictional torque coefficient, τ_{fr2} (N-m, lb_f-ft).

W5(R) Second exponent, x2. This is used on the speed ratio used with the frictional torque coefficient τ_{fr2}. If not entered, a default value of 2.0 is used.

W6(R) Third frictional torque coefficient, τ_{fr3} (N-m, lb_f-ft).

W7(R) Third exponent, x3. This is used on the speed ratio used with the frictional torque coefficient τ_{fr3}. If not entered, a default value of 3.0 is used.

7.7.18 Card CCC0308, Turbine Variable Inertia

This card is used only for the TURBINE components and is optional. If this card is not entered, the moment of inertia of the turbine stage is constant and is given by Word 2 of Card CCC0300. If this card is entered, the moment of inertia, I_t, of the turbine is calculated as

$$I_t = I_{tn} \qquad \text{for } \left|\frac{\omega}{\omega_R}\right| < S_{TI}$$

$$I_t = I_{t0} + I_{t1}\left|\frac{\omega}{\omega_R}\right| + I_{t2}\left|\frac{\omega}{\omega_R}\right|^2 + I_{t3}\left|\frac{\omega}{\omega_R}\right|^3 \qquad \text{for } \left|\frac{\omega}{\omega_R}\right| \geq S_{TI}$$

where ω is the turbine speed, ω_R is the rated turbine speed and is obtained from Word 6 of Card CCC0400. Fewer than five words may be entered. The default values of the coefficients are 0.0.

W1(R) Turbine inertia critical speed ratio, S_{TI}. When the absolute value of the turbine speed ratio is greater than or equal to S_{TI}, the cubic expression for the inertia is used. When the absolute value of the turbine speed ratio is less than S_{TI}, the inertia (I_{tn}) from Word 2 of Card CCC0300 is used.

W2(R) Constant inertia coefficient, I_{t0} (kg-m^2, lb$_m$-ft^2).

W3(R) Linear inertia coefficient, I_{t1} (kg-m^2, lb$_m$-ft^2).

W4(R) Quadratic inertia coefficient, I_{t2} (kg-m^2, lb$_m$-ft^2).

W5(R) Cubic inertia coefficient, I_{t3} (kg-m^2, lb$_m$-ft^2).

7.7.19 Cards CCCN901 through CCCN909, Separator Junction Maximum Volume Fractions

These cards are optional for the SEPARATR component, and they are not allowed for the BRANCH, JETMIXER, TURBINE, FWHTR, and ECCMIX components. The value N should follow the same approach as used for Cards CCCN101 through CCCN109. The defaults indicated for each word are used if no cards are entered.

W1(R) Enter 1.0. The default value is 1.0.

W2(R) Enter 1.0. The default value is 1.0.

W3(R) Maximum volume fraction. This entry is for the SEPARATR component. This is only used for the simple separator. For the output junction (N=1), this quantity (VGMAX) is the vapor/gas volume (void) fraction used when the vapor/gas volume (void) fraction in the separator exceeds VOVER (Cards CCC1101 through CCC1109, Word 7). For the liquid fallback junction (N=2), this quantity (VFMAX) is the liquid volume fraction used when the liquid volume fraction in the separator exceeds VUNDER (Cards CCC2101 through CCC2109, Word 7). This word is not used for the separator inlet junction (N=3). The default value is 1.0.

7.7.20 Card CCC0400, Turbine Performance Data

This card is used only for TURBINE components and is required for TURBINE components..

W1(I) Turbine type

0 = Two-row impulse stage group.

1 = General impulse-reaction stage group.

2 = Constant efficiency stage group.

3 = User specified efficiency stage group.

W2(R) Actual efficiency η_o at the maximum efficiency design point.

W3(R) Design reaction fraction, r. This is the fraction of the enthalpy decrease that takes place in the rotating blade system.

W4(R) Mean stage radius, R (m, ft).

W5(R) Rated power, $\dot{W}_R$ (W, MW). This word is required for a Type-3 turbine and is not used for the other types.

W6(R) Rated speed, ω_R (rad/s, rev/min). This word is optional and if not entered is set to Word 1 of Card CCC0300.

7.7.21 Card CCC0401, Type-3 Turbine Performance Data

This card is required only for Type-3 (see Word 1 of Card CCC0400) TURBINE components. The efficiency is calculated as a function of normalized speed and load

$$\eta = \eta_R\left[a_0 + a_1\left(\frac{\omega}{\omega_R}\right) + a_2\left(\frac{\omega}{\omega_R}\right)^2 + a_3\left(\frac{\omega}{\omega_R}\right)^3\right]\left[b_0 + b_1\left(\frac{\dot{W}}{\dot{W}_R}\right) + b_2\left(\frac{\dot{W}}{\dot{W}_R}\right)^2 + b_3\left(\frac{\dot{W}}{\dot{W}_R}\right)^3\right]$$

where η_R is obtained from Word 2 of Card CCC0400, ω is the turbine speed, ω_R is the rated turbine speed and is obtained form Word 6 of Card CCC0400, $\dot{W}$ is the turbine power, and $\dot{W}_R$ is the rated turbine power and is obtained form Word 5 of Card CCC0400. Fewer than eight words may be entered. The default values are 1.0 for a_0 and b_0 and 0.0 for the other coefficients.

W1(R) Constant speed coefficient, a_0.

W2(R) Linear speed coefficient, a_1.

W3(R) Quadratic speed coefficient, a_2.

W4(R) Cubic speed coefficient, a_3.

W5(R) Constant load ceofficient, b_0.

W6(R) Linear load coefficient, b_1.

W7(R) Quadratic load coefficient, b_2.

W8(R) Cubic load coefficient, b_3.

7.7.22 Card CCC0500, GE Separator Data

This card is optional for the GE separator. If this card is missing and the GE separator has been specified on Card CCC0002, the default values will be used. If the card is present, all eight values must be specified.

W1(R) Radius of larger pickoff ring at first stage of a two-stage separator (m, ft). Default = 0.0857208 m.

W2(R) Standpipe flow area (m^2, ft^2). Default = 0.018637 m^2.

W3(R) Separator nozzle exit area (m^2, ft^2). Default = 0.01441 m^2.

W4(R) Radius of separator hub at inlet (m, ft). Default = 0.0809585 m.

W5(R) Swirl vane angle relative to the horizontal (degrees). Default = 48 degrees.

W6(R) Liquid carryover coefficient for upper separating stages. Default = 0.009 for two-stage separator and 0.110 for three-stage separator.

W7(R) Vapor/gas carryunder coefficient for upper separating stages. Default = 0.0004.

W8(R) Axial distance between exit of first stage discharge passage and swirl vanes (m, ft). Default = 0.2127 m for two-stage separator and 0.45083 m for three-stage separator.

7.7.23 Card CCC0501, GE Separator First Stage Data

This card is optional for the GE separator. If this card is missing and the GE separator has been specified on Card CCC0002, the default values will be used. If the card is present, all nine values must be specified.

W1(R) Liquid film void profile coefficient. Default = 110.0.

W2(R) Vapor/gas core void profile coefficient. Default = 0.5.

W3(R) Separator wall inner radius (m, ft). Default = 0.10794 m.

W4(R) Pickoff ring inner radius (m, ft). Default = 0.069875 m for two-stage separator and 0.0857208 m for three-stage separator.

W5(R) Discharge passage flow area (m^2, ft^2). Default = 0.0415776 m^2 for two-stage separator and 0.0096265 m^2 for three-stage separator.

W6(R) Discharge passage hydraulic diameter (m, ft). Default = 0.045558 m for two-stage separator and 0.025399 m for three-stage separator.

W7(R) Separating barrel length (m, ft). Default = 0.877845 m for two-stage separator and 1.0699 m for three-stage separator.

W8(R) Discharge passage loss coefficient. Default = 10.0 for two-stage separator and 2.5 for three-stage separator.

W9(R) Discharge passage effective $\frac{L}{D}$ coefficient. Default = 450.0 for two-stage separator and 53.44 for three-stage separator.

7.7.24 Card CCC0502, GE Separator Second Stage Data

This card is optional for the GE separator. If this card is missing and the GE separator has been specified on Card CCC0002, the default values will be used. If the card is present, all nine values must be specified.

W1(R) Liquid film void profile coefficient. Default = 20.0.

W2(R) Vapor/gas core void profile coefficient. Default = 0.25.

W3(R) Separator wall inner radius (m, ft). Default = 0.06985 m for two-stage separator and 0.10794 m for three-stage separator.

W4(R) Pickoff ring inner radius (m, ft). Default = 0.06032 m for two-stage separator and 0.0952453 m for three-stage separator.

W5(R) Discharge passage flow area (m^2, ft^2). Default = 0.0029133 m^2 for two-stage separator and 0.0096265 m^2 for three-stage separator.

W6(R) Discharge passage hydraulic diameter (m, ft). Default = 0.0121699 m for two-stage separator and 0.025399 m for three-stage separator.

W7(R) Separating barrel length (m, ft). Default = 0.16255 m for two-stage separator and 0.384156 m for three-stage separator.

W8(R) Discharge passage loss coefficient. Default = 0.5 for two-stage separator and 1.429 for three-stage separator.

W9(R) Discharge passage effective $\frac{L}{D}$ coefficient. Default = 95.85 for two-stage separator and 194.64 for three-stage separator.

7.7.25 Card CCC0503, GE Separator Third Stage Data

This card is optional for the GE separator. If this card is missing and the GE three-stage separator has been specified on Card CCC0002, the default values will be used. If the card is present, all nine values must be specified.

W1(R) Liquid film void profile coefficient. Default = 20.0.

W2(R) Vapor/gas core void profile coefficient. Default = 0.55.

W3(R) Separator wall inner radius (m, ft). Default = 0.10794 m.

W4(R) Pickoff ring inner radius (m, ft). Default = 0.0984201 m.

W5(R) Discharge passage flow area (m^2, ft^2). Default = 0.0096265 m^2.

W6(R) Discharge passage hydraulic diameter (m, ft). Default = 0.025399 m.

W7(R) Separating barrel length (m, ft). Default = 0.384156 m.

W8(R) Discharge passage loss coefficient. Default = 2.563.

W9(R) Discharge passage effective $\frac{L}{D}$ coefficient. Default = 424.96.

7.7.26 Card CCC0600, GE Dryer Data

This card is optional for the GE dryer. If this card is missing and the GE dryer has been specified on Card CCC0002, the default values will be used. If the card is present, all three values must be specified.

W1(R) Vapor/gas velocity at dryer inlet below which there is 0% liquid carryover (m/s, ft/s). Default = 1.5 m/s.

W2(R) Vapor/gas velocity at dryer inlet above which there is 100% liquid carryover (m/s, ft/s). Default = 6.0 m/s.

W3(R) Range of dryer inlet quality where dryer carryover changes from 0 to 100% when dryer inlet vapor/gas velocity is between lower and upper values. Default = 0.05.

7.7.27 Card CCC0701 Branch, Separator, Jetmixer, Turbine, Feedwater Heater, or ECC Mixer Volume Noncondensable Mass Fractions

This card is optional. If omitted, the noncondensable mass fractions are obtained from the noncondensable mass fractions entered on Card 115.

W1-WN(R) Mass fractions for the noncondensable species entered on Card 110. The number of words should be the same as on Card 110. The sum of the noncondensable mass fractions must sum to one within a relative error of 1.0×10^{-10}.

7.8 Valve Junction Component

A valve junction component is indicated by VALVE for Word 2 on Card CCC0000. For major edits, minor edits, and plot variables, the junction in the valve junction component is numbered CCC000000.

7.8.1 Cards CCC0101 through CCC0109, Valve Junction Geometry

This card (or cards) is required for valve junction components.

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. An old or an expanded format can be used to connect volumes. In the old format (only allowed for connection to 1-D components), use CCC000000 if the connection is to the inlet side of the component and use CCC010000 if the connection is to the outlet side of the component. In the expanded format, the connection code for 1-D components is CCCXX000F [where CCC is the component number, XX is the volume number (greater than 00 and less than 100) for pipes/annuli/pressurizers, XX is 01 for all other 1-D components, and F indicates the face number]. A nonzero F specifies the expanded format. The number F equal to 1 and 2 specifies the inlet and outlet faces for the first coordinate direction (x or r), which is a 1-D volume's coordinate direction (x) (see Section 2.1 of Volume II of this manual). The number F equal to 3 through 6 specifies crossflow (y or z) for 1-D volumes. The number F equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction (y or θ); F equal to 5 and 6 would do the same for the third coordinate direction (z). For connecting to a time-dependent volume using the old format, both CCC000000 and CCC010000 are allowed. For connecting to a time-dependent volume using the expanded format, only the number F equal to 1 or 2 is allowed. Section 4.4 in this Appendix discusses this further.

W2(I) To connection code to a component. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.

W3(R) Junction area (m^2, ft^2). This quantity is the full open area of the valve except in the case of a relief valve. For valves other than motor, servo, and relief valves, if this area is input as zero, the area is set to the minimum area of adjoining volumes; if nonzero, this area is used. For motor or servo valves, this quantity must be greater than zero. For relief valves, this term is the valve inlet throat area; if this term is input as zero, it will default to the area calculated from the inlet diameter term input on Cards CCC0301 through CCC0309, in which case the inlet diameter term cannot be input as zero. For relief valves, if both this area and the inlet diameter are input as nonzero, this area will be used but must agree with the area calculated from the inlet diameter within 10^{-5} m^2; however, if this area is input as nonzero and the inlet diameter is input as zero, the inlet diameter will default to the diameter calculated from this area. When an abrupt area change model is specified, the area must be less than or equal to the minimum of the adjoining volume areas. A closed valve is treated as a time dependent junction with no flow.

W4(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or zero. A variable loss coefficient may be specified (see Section 7.8.3 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W5(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. A variable loss coefficient may be specified (see Section 7.8.3 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W6(I) Junction control flags. This word has the packed format jefvcahs. It is not necessary to input leading zeros.

The digit j is not used and should be input as zero (j = 0). The jet junction model is not used.

The digit e specifies the modified PV term in the energy equations; e = 0 specifies that the modified PV term will not be applied, and e = 1 specifies that the modified PV term will be applied.

The digit f specifies CCFL options; f = 0 specifies that the CCFL model will not be applied, and f = 1 specifies that the CCFL model will be applied.

The digit v specifies stratification entrainment/pullthrough options, where this model is for junctions connected to a horizontal or vertical volume; v = 0 specifies the model is not applied; v = 1 specifies an upward-oriented junction from a horizontal volume (offtake volume must be vertical); v = 2 specifies a downward-oriented junction from a horizontal volume (offtake volume must be vertical); and v = 3 specifies a centrally (side) located junction from a horizontal or vertical volume. For v = 1 or 2, the horizontal volume flow area must be greater than or equal to the offtake volume flow area.

The digit c specifies choking options; c = 0 specifies that the choking model will be applied, and c = 1 specifies that the choking model will not be applied.

The digit a specifies area change options; a = 0 specifies either a smooth area change or no area change, a = 1 specifies full abrupt area change model (code-calculated K_{loss}, area apportioning at a branch, restricted junction area, and extra interphase drag), and a = 2 specifies a partial abrupt area change model (no code-calculated K_{loss}, but includes area apportioning at a branch, restricted junction area, and extra interphase drag). All options may be input for a motor or servo valve. If the smooth area change option is input, then a

C_v table must be input; or, if no C_v table is input, then one of the abrupt area change options must be input. For all other valves, one of the abrupt area change options must be input. It is recommended that the abrupt area change model (a = 1 or a = 2) be used at branches.

The digit h specifies nonhomogeneous or homogeneous; h = 0 specifies the nonhomogeneous (two-velocity momentum equations) option, and h = 1 or 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 1 or 2), the major edit printout will show h = 1.

The digit s specifies momentum flux options; s = 0 specifies momentum flux in both the to volume and the from volume, s = 1 specifies momentum flux in the from volume but not in the to volume, s = 2 specifies momentum flux in the to volume but not in the from volume, and s = 3 specifies no momentum flux in either the to or the from volume.

W7(R) Subcooled discharge coefficient. This quantity is applied only to subcooled liquid choked flow calculations. The quantity must be > 0 and $\leq$ 2.0. If W7, W8, and W9 are missing, then W7, W8, and W9 are set to 1.0.

W8(R) Two-phase discharge coefficient. This quantity is applied only to two-phase choked flow calculations. The quantity must be > 0 or $\leq$ 2.0. If W7 is entered, and W8 and W9 are missing, then W8 and W9 are set to 1.0.

W9(R) Superheated discharge coefficient. This quantity is applied only to superheated vapor/gas choked flow calculations. The quantity must be > 0 and $\leq$ 2.0. If W7 and W8 are entered, and W9 is missing, then W9 is set to 1.0.

7.8.2 Card CCC0110, Valve Junction Diameter and CCFL Data

This card is optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to specify the junction hydraulic diameter for the interphase drag calculation (i.e., f = 0 in Word 6 of Cards CCC0101 through CCC0109), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through (will not be used). If this card is being used for the CCFL model (i.e., f = 1 in Word 6 of Cards CCC0101 through CCC0109), then enter all four words for the appropriate CCFL model if values different from the default values are used.

W1(R) Junction hydraulic diameter, D_j (m, ft). This is the junction hydraulic diameter used in the CCFL correlation equation, interphase drag, and form loss Reynolds number. This number must be $\geq$ 0. This number should be computed from $4.0 \bullet \left(\frac{\text{junction area}}{\text{wetted perimeter}}\right)$. If a zero is entered or if the default is used, the junction diameter is computed from

$2.0 \bullet \left(\frac{\text{junction area}}{\pi}\right)^{0.5}$. See Word 3 of Cards CCC0101 through CCC0109 for the junction area.

W2(R) Flooding correlation form, β. If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be ≥ 0 and ≤ 1. The default value is 0 (Wallis form). See Section 3 of Volume I for details of the model.

W3(R) Vapor/gas intercept, c. This is the vapor/gas intercept used in the CCFL correlation (when $H_f^{1/2} = 0$) and must be > 0. The default value is 1.

W4(R) Slope, m. This is the slope used in the CCFL correlation and must be > 0. The default value is 1.

7.8.3 Card CCC0111, Valve Junction Form Loss Data

This card is optional. The user-specified form loss coefficients are given in Words 4 and 5 of Cards CCC0101 through CCC0109 if this card is not entered. If this card is entered, the form loss coefficients depend on the flow conditions and are calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficients; A_F, A_R, B_F, B_R, C_F, and C_R are user-specified constants. A_F and A_R are Words 4 and 5 of Cards CCC0101 through CCC0109; B_F, B_R, C_F, and C_R are Words 1, 2, 3, and 4 on this card (CCC0111); and Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculations, then enter all four words for the appropriate expression.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to zero.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to zero.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to zero.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to zero.

7.8.4 Card CCC0113, Valve Junction Face Placement Data

This card is optional. It is used to improve the graphical display of the hydrodynamic nodes. It is used to resolve problems with converging and diverging flows, that is, multiple junctions attached to the same face of a volume. With the standard input, each junction attached to the same face of a volume would be superimposed on the graphical display since each junction would be attached to the center of the volume face. For junctions with this card, the point of leaving the "from" volume and entering the "to" volume is allowed to be other than the center of the faces. The volume face is perpendicular to one of the coordinate directions. The attachment position is given by specifying the coordinates on the remaining two directions. Four words are entered on the card; two words for the coordinates for the "from" face, and two words for the two coordinates for the "to" face. The coordinates are entered in the order x, then y, then z, skipping the coordinate direction perpendicular to the face. The values are dimensionless. The actual coordinates are given by these values times the position change in moving from the volume center to the face in that direction. A value of 0.0 means no change from the center of the volume in that direction, and 1.0 means move to the edge of the volume in that direction. Positive or negative numbers can be entered, and the sign indicates moving in the positive or negative direction along that coordinate. A value greater than 1.0 can be used to get separation; the maximum allowed value is 25.0. The default is 0.0.

W1(R) First remaining coordinate value for the "from" face (dimensionless).

W2(R) Second remaining coordinate value for the "from" face (dimensionless).

W3(R) First remaining coordinate value for the "to" face (dimensionless).

W4(R) Second remaining coordinate value for the "to" face (dimensionless).

7.8.5 Card CCC0201, Valve Junction Initial Conditions

This card is required for valve junction components.

W1(I) Control word. If zero, the next two words are velocities; if one, the next two words are mass flow rates.

W2(R) Initial liquid velocity or initial liquid mass flow rate. This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lb_m/s), depending on the control word.

W3(R) Initial vapor/gas velocity or initial vapor/gas mass flow rate This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lb_m/s), depending on the control word.

W4(R) Interface velocity (m/s, ft/s). Enter zero.

7.8.6 Card CCC0300, Valve Type

This card is required to specify the valve type.

W1(A) Valve type. This word must contain one of the following: CHKVLV for a check valve, TRPVLV for a trip valve, INRVLV for an inertial swing check valve, MTRVLV for a motor valve, SRVVLV for a servo valve, or RLFVLV for a relief valve.

7.8.7 Cards CCC0301 through CCC0399, Valve Data and Initial Conditions

These cards are required for valve junction components. Six different types of valves are allowed. The following words may be placed on one or more cards, and the card numbers need not be consecutive. The card format of these cards depends on the valve type.

7.8.7.1 Check Valve. This behaves as an <u>on</u>, <u>off</u> switch. If the valve is <u>on</u>, then it is fully open; and if the valve is <u>off</u>, it is fully closed.

W1(I) Check valve type. Enter +1 for a static pressure-controlled check valve (no hysteresis), 0 for a static pressure/flow-controlled check valve (has hysteresis effect), or -1 for a static/dynamic pressure-controlled check valve (has hysteresis effect). It is recommended that 0 be used for most calculations, as it is more stable (i.e., less noisy and less oscillations) than +1 or -1.

W2(I) Check valve initial position. The valve is initially open if zero, closed if one.

W3(R) Closing back pressure (Pa, lb_f/in^2).

W4(R) Leak ratio. This is the fraction of the junction area for the leakage when the valve is nominally closed. If omitted or input as zero, then either the smooth or the abrupt area change model may be specified. If input as nonzero, then the abrupt area change model must be specified.

7.8.7.2 Trip Valve. This behaves as an <u>on</u>, <u>off</u> switch as described for the check valve.

W1(I) Trip number. This must be a valid trip number. If the trip is false, the valve is closed; if the trip is true, the valve is open.

7.8.7.3 Inertial Valve. This behaves realistically in that the valve area varies considering the hydrodynamic forces and the flapper inertia, momentum, and angular acceleration. The abrupt area change model must be specified. The body forces from the "to" volume are applied to the flapper.

W1(I) Latch option. The valve can open and close repeatedly if the latch option is zero. When W1 = 1, the valve either opens or closes only once if the initial angle is between the maximum and minimum. If the flapper starts at either the maximum or minimum angle it will not move. When W1 = 2, the flapper will latch only at the maximum position. If it starts at the maximum, it will not move.

W2(I) Valve initial condition. The valve is initially open if zero, initially closed if one.

W3(R) Cracking pressure (Pa, lb_f/in^2).

W4(R) Leakage fraction. Fraction of the junction area for leakage when the valve is nominally closed.

W5(R) Initial flapper angle (degrees). The flapper angle must be within the minimum and maximum angles specified in Words 6 and 7.

W6(R) Minimum flapper angle (degrees). This must be greater than or equal to zero.

W7(R) Maximum flapper angle (degrees). This must be greater than the minimum angle specified in Word 6.

W8(R) Moment of inertia of valve flapper ($kg \bullet m^2$, $lb_m \bullet ft^2$).

W9(R) Initial angular velocity (rad/s).

W10(R) Moment length of flapper (m, ft).

W11(R) Radius of flapper (m, ft).

W12(R) Mass of flapper (kg, lb_m).

7.8.7.4 Motor Valve. This behaves realistically in that the valve area varies as a function of time by either of two models specified by the user. The user must also select the model for valve hydrodynamic losses by specifying either the smooth or the abrupt area change model. If the smooth area change model is selected, a table of flow coefficients must also be input as described in Cards CCC0400 through CCC0499, Valve CSUBV Table, Section 7.8.8. If the abrupt area change model is selected, a flow coefficient table cannot be input.

W1(I) Open trip number.

W2(I) Close trip number. Both the open and close trip numbers must be valid trips. When both trips are false, the valve remains at its current position. When one of the trips is true, the valve opens or closes according to the valve change rate (see Word 3 and Word 5) depending on which trip is true. The transient will be terminated if both trips are true at the same time.

W3(R) Valve change rate (s^{-1}). If Word 5 is not entered, this quantity is the rate of change of the normalized valve area as the valve opens or closes. If Word 5 is entered, this quantity is the rate of change of the normalized valve stem position. This word must be greater than zero.

W4(R) Initial position. This number is the initial normalized valve area or the initial normalized stem position depending on Word W5. This quantity must be between 0.0 and 1.0.

W5(I) Valve table number. If this word is omitted or input as zero, the normalized valve area is determined by the valve change rate and the trips. If this word is input as nonzero, the normalized valve stem position is determined by the valve change rate and the trips; and the normalized valve area is determined from a general table (indicated by this word) containing normalized valve area versus normalized valve stem position. Input for general tables is discussed in Section 11. For this case, the normalized valve stem position is input as the *argument value* and the normalized valve area is input as the *function value*.

7.8.7.5 Servo Valve. This behaves as described for a motor valve except that the valve flow area or valve stem position is calculated by a control system. Input for control systems is discussed in Section 14. Input specifying the hydrodynamic losses for servo valves is also identical to that for motor valves.

W1(I) Control variable number. The value of the indicated control variable is either the normalized valve area or the normalized valve stem position, depending on whether Word 2 is entered.

W2(I) Valve table number. If this word is not entered, the control variable value is the normalized flow area. If this word is entered, the control variable value is the normalized stem position, and the normalized valve area is determined from a general table (indicated by this word) containing a table of normalized valve area versus normalized valve stem position. Input for general tables is discussed in Section 11. For this case, the normalized valve stem position is input as the *argument value* and the normalized valve areas is input as the *function value*.

7.8.7.6 Relief Valve. The valve area varies, considering the hydrodynamic forces and the valve mass, momentum, and acceleration. The abrupt area change model must be specified. The junction area input by Cards CCC0101 through CCC0199 is the valve inlet area.

W1(I) Valve initial condition. The valve is initially closed if zero, open if one.

W2(R) Inlet diameter (m, ft). This is the inside diameter of the valve inlet. If this term is input as zero, it will default to the diameter calculated from the junction area input on Cards CCC0101 through CCC0109. If both this diameter and the junction area are input as nonzero, care must be taken that these terms are input with enough significant digits so that the areas agree within 10^{-5} m^2. If the junction area is input as zero, then this diameter must be input as nonzero.

W3(R) Valve seat diameter (m, ft). Nonzero input is required. This term is the outside diameter of the valve seat, including the minimum diameter of the inner adjustment ring. This term must also be greater than or equal to the inlet diameter.

W4(R) Valve piston diameter (m, ft). If input as zero, the default is to the valve seat diameter.

W5(R) Valve lift (m, ft). Nonzero input is required. This is the distance the valve piston rises above the valve seat at the fully open position.

W6(R) Maximum outside diameter of the inner adjustment ring (m, ft). If this input is zero, it will default to the valve seat diameter; in which case W7, following, must be input as zero. If this input is nonzero, the value must be greater than or equal to the valve seat diameter. If input is greater than the valve seat diameter, a nonzero input of W7, is allowed. Also refer to the warning stated for W9.

W7(R) Height of outside shoulder relative to the valve seat for inner adjustment ring (m, ft). Input of a positive, nonzero value is not allowed. Input of a zero value is required if W6 preceding is defaulted or input equal to the valve seat diameter. If the shoulder is below the seat, this distance is negative. Also refer to the warning stated for W9.

W8(R) Minimum inside diameter of the outer adjustment ring (m, ft). If this input is zero, it will default to the valve piston diameter, in which case W9 must be input as positive and nonzero. If this input is nonzero, the value must be greater than or equal to the valve piston diameter. Input of a negative W9 is allowed only if this diameter is greater than the valve piston diameter. Also refer to the warning stated for W9.

W9(R) Height of inside bottom edge relative to the valve seat for outer adjustment ring (m, ft). This may be input as positive, zero, or negative. If this input is negative, then W8 preceding must be greater than the valve piston diameter. If the bottom edge is below the valve seat, this distance is negative. WARNING: Input of this term and terms W6, W7, and W8 preceding must be done with care to ensure that the resultant gap between the adjustment rings is positive and nonzero; otherwise, an input error will result.

W10(R) Bellows average diameter (m, ft). If this term is input as zero, it will default to the valve piston diameter, resulting in a model not containing a bellows for which the valve bonnet region is vented to the atmosphere.

W11(R) Valve spring constant (N/m, lb_f/ft). Positive, nonzero input is required.

W12(R) Valve setpoint pressure (Pa, lb_f/in^2). Positive input is required.

W13(R) Valve piston, rod, spring, bellows mass (kg, lb_m). Nonzero input is required.

W14(R) Valve damping coefficient (N·s/m, lb_f·s/ft).

W15(R) Bellows inside pressure (Pa, lb_f/in^2). Defaults to standard atmospheric pressure if omitted or input as zero.

W16(R) Initial stem position. This is the fraction of total lift and is required if W1 is input as one. Total lift is input as W5.

W17(R) Initial valve piston velocity (m/s, ft/s). This must be zero or omitted if W1 is input as zero.

7.8.8 Cards CCC0400 through CCC0499, Valve CSUBV Table

The CSUBV table may be input only for motor and servo valves. If the CSUBV table is input, the smooth area change model must be specified on the valve junction geometry cards (Cards CCC0101 through CCC0109). If the smooth area change model is specified, a CSUBV table must be input.

The CSUBV table contains forward and reverse flow coefficients as a function of normalized flow area.

7.8.8.1 Cards CCC0400, Factors. This card is optional. The factors apply to the normalized flow area and the flow coefficient entries in the CSUBV table (Cards CCC0401 through CCC0499).

W1(R) Normalized flow area factor.

W2(R) Flow coefficient factor.

7.8.8.2 Cards CCC0401 through CCC0499, Table Entries. The table is entered by using three-word sets on each card. Sets may be entered one or more per card and may be split across cards. The total number of words must be a multiple of the set size. W1 is the flow area and must be normalized. The factor W1 on Card CCC0400 can be used to modify the normalized flow area entered on Cards CCC0401 through CCC0499. In either case, the implication is that if the valve is fully closed, the normalized term is zero. If the valve is fully open, the normalized term is one. Any value may be input that is between zero and one. The forward and reverse flow coefficients are W2 and W3, respectively. The code internally converts flow coefficients (CSUBV) to energy loss coefficients (K) by the formula $K = 2CA_j^2/(\rho_o CSUBV^2)$, where ρ_o is density of liquid light water at 60 ^oF (288.71 K), 14.7 lb_f/in^2

(1.0x10^5 Pa), C is $9.3409\text{x}10^8 \frac{\left(\frac{\text{gal}}{\text{min}}\right)^2 \text{lb}_\text{m}}{\text{ft}^7\left(\frac{\text{lb}_\text{f}}{\text{in}^2}\right)}$ and A_j is the full open valve area. The value of the density ρ_o is 62.4 lb_m/ft^3 (999.09 kg/m^3). On Card CCC0400, W2 may be used to modify the CSUBV flow coefficients entered on Cards CCC0401 through CCC0499. This can allow conversion to a different set of units. A smooth area change must be specified in W6 on Card CCC0101 to use the CSUBV table. CSUBV is entered in British units only.

W1(R) Normalized flow area.

W2(R) Forward flow coefficient (CSUBV) $\{(\text{gal}/\text{min})/[(\text{lb}_\text{f}/\text{in}^2)^{0.5}]\}$. The CSUBV is input in British units only and is converted to SI units using 7.598055E-7 $\frac{\text{m}^3\left(\frac{\text{lb}_\text{f}}{\text{in}^2}\right)^{0.5}}{\left(\frac{\text{gal}}{\text{min}}\right)\text{Pa}^{0.5}}$ as the conversion factor.

W3(R) Reverse flow coefficient (CSUBV) $\{(\text{gal}/\text{min})/[(\text{lb}_\text{f}/\text{in}^2)^{0.5}]\}$.

7.9 Pump Component

A pump component is indicated by PUMP for Word 2 on Card CCC0000. A pump consists of one volume and two junctions, one attached to each end of the volume. For major edits, minor edits, and plot variables, the volume in the pump component is numbered as CCC010000. The pump junctions are numbered CCC010000 for the inlet junction and CCC020000 for the outlet junction.

7.9.1 Cards CCC0101 through CCC0107, Pump Volume Geometry

This card (or cards) is required for a pump component. The seven words can be entered on one or more cards, and the card numbers need not be consecutive.

W1(R) Volume flow area (m^2, ft^2).

W2(R) Length of volume (m, ft).

W3(R) Volume of volume (m^3, ft^3). The program requires that the volume equals the volume flow area times the length (W3 = W1•W2). At least two of the three quantities, W1, W2, W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the words are zero, the volume must equal the area times the length within a relative error of 0.000001.

W4(R) Azimuthal (horizontal) angle (degrees). The absolute value of this angle must be $\leq$ 360 degrees and is defined as a positional quantity. This angle is in the horizontal x-y plane. The angle 0 degrees is on the x axis, and the angle 90 degrees is on the y axis. Positive angles are rotated from the x axis toward the y axis. This quantity is not used in the calculation but is specified for automated drawing of nodalization diagrams.

W5(R) Inclination (vertical) angle (degrees). The absolute value of this angle must be $\leq$ 90 degrees. The angle 0 degrees is horizontal; positive angles have an upward direction, i.e., the outlet is at a higher elevation than the inlet. This angle is used in the interphase drag calculation and for automated drawing of nodalization diagrams. For this component, this angle is not used to decide if the horizontal or vertical flow regime map is used. Rather, the high mixing flow regime map is used.

W6(R) Elevation change (m, ft). A positive value is an increase in elevation. The absolute value of this quantity must be equal to or less than the volume length. If the inclination (vertical) angle orientation is zero, this quantity must be zero. If the inclination (vertical) angle is nonzero, this quantity must also be nonzero and have the same sign. The elevation change is used in the gravity head and in checking loop closure. See Section 2.4.1 of Volume II of the manual for further discussion. A calculated elevation angle is determined by the arcsin of the ratio of the elevation change (this word) and the volume length (Word 2). This calculated elevation angle is used in the additional stratified force term.

W7(I) Volume control flags. This word has the packed format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scaler oriented and coordinate direction oriented flags. Only one value for a scaler oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. This word enters the scaler oriented flags and the x-coordinate flag. The pump component forces all volume flags except for the e digit, and y- and z-coordinate flags are not read. The effective format is 000000e.

The digit t is not used and must be input as zero (t = 0). Thermal stratification is not used in a pump component.

The digit l is not used and must be entered as zero (l = 0). Level tracking is not used in a pump component.

The digit p is not used and must be input as zero (p = 0). The major edit output will show p = 1. The water packing scheme is not used.

The digit v is not used and must be input as zero (v = 0). The major edit output will show v = 1. The vertical stratification model is not used.

The digit b is not used and must be input as zero (b = 0). The major edit will show b = 0. The rod bundle interphase friction is not used.

The digit f that normally specifies whether wall friction is to be computed is not used and a 0 must be entered. No wall friction is computed for a pump, since it is included in the homologous pump data. The major edit output will show f = 1, which indicates that the no friction flag is set.

The digit e specifies if nonequilibrium or equilibrium is to be used; e = 0 specifies that a nonequilibrium (unequal temperature) calculation is to be used, and e = 1 specifies that an equilibrium (equal temperature) calculation is to be used. Equilibrium volumes should not be connected to nonequilibrium volumes. The equilibrium option is provided only for comparison to other codes.

7.9.2 Card CCC0108, Pump Inlet (Suction) Junction

This card is required for a pump component.

W1(I) Volume code of connecting volume on inlet side. This refers to the component from which the junction coordinate direction originates. An old or an expanded format can be used to connect volumes. In the old format (only allowed for connection to 1-D components), use CCC000000 if the connection is to the inlet side of the component and use CCC010000 if the connection is to the outlet side of the component. In the expanded format, the connection code for 1-D components is CCCXX000F [where CCC is the component number, XX is the volume number (greater than 00 and less than 100) for 1-D pipes/annuli/pressurizers, XX is 01 for all other 1-D components, and F indicates the face number]. A nonzero F specifies the expanded format. The number F equal to 1 and 2 specifies the inlet and outlet faces for the first coordinate direction, which is a 1-D volume’s coordinate direction (see Section 2.1 of Volume II of this manual). The number F equal to 3 through 6 specifies crossflow for 1-D volumes. The number F equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction; F equal to 5 and 6 would do the same for the third coordinate direction. For connecting to a time-dependent volume using the old format, both CCC000000 and CCC010000 are allowed. For connecting to a time-dependent volume using the expanded format, only the number F equal to 1 or 2 is allowed. Section 4.4 in this Appendix discusses this further.

W2(R) Junction area (m^2, ft^2). If zero, the area is set to the minimum of the volume areas of adjacent volumes. If an abrupt area change, the area must be equal to or less than the minimum of the adjacent volume areas. If a smooth area change, no restrictions exist.

W3(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or zero. A variable loss coefficient may be specified (see Section 7.9.6 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W4(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. A variable loss coefficient may be specified (see Section 7.9.6 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W5(I) Junction control flags. This word has the packed format jefvcahs. It is not necessary to input leading zeros.

The digit j is not used and should be input as zero (j = 1). The jet junction model is not used.

The digit e is not used and should be input as zero (e = 0).

The digit f specifies CCFL options; f = 0 specifies that the CCFL model will not be applied, and f = 1 specifies that the CCFL model will be applied.

The digit v is not used and should be input as zero (v = 0). The stratification entrainment/pullthrough model is not used.

The digit c specifies choking options; c = 0 specifies that the choking model will be applied, and c = 1 specifies that the choking model will not be applied.

The digit a specifies area change options; a = 0 specifies either a smooth area change or no area change, a = 1 specifies full abrupt area change model (code-calculated K_{loss}, area apportioning at a branch, restricted junction area, and extra interphase drag), and a = 2 specifies a partial abrupt area change (no code-calculated K_{loss}, but includes area apportioning at a branch, restricted junction area, and extra interphase drag).

The digit h specifies nonhomogeneous or homogeneous; h = 0 specifies the nonhomogeneous (two-velocity momentum equations) option, and h = 1 or 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 1 or 2), the major edit printout will show a one.

The digit s is not used and should be input as zero (s = 0).

7.9.3 Card CCC0109, Pump Outlet (Discharge) Junction

This card is required for a pump component. The format for this card is identical to Card CCC0108 except data are for the outlet junction.

7.9.4 Card CCC0110, Pump Inlet (Suction) Junction Diameter and CCFL Data

This card is optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to specify only the junction hydraulic diameter for the interphase drag calculation (i.e., f = 0 in Word 5 of Card CCC0108), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If the card is being used for the CCFL model (i.e., f = 1 in Word 5 of Card CCC0108), then enter all four words for the appropriate CCFL model if values different from the default values are desired.

W1(R) Junction hydraulic diameter, D_j (m, ft). This is the junction hydraulic diameter used in the CCFL correlation equation, interphase drag, and form loss Reynolds number. This number must be $\geq$ 0. This number should be computed from $4.0 \bullet \left(\frac{\text{junction area}}{\text{wetted perimeter}}\right)$. If a zero is entered or the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{junction area}}{\pi}\right)^{0.5}$. See Word 2 of Card CCC0108 for the junction area.

W2(R) Flooding correlation form, β. If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be $\geq$ 0 and $\leq$ 1. The default value is 0 (Wallis form). See Section 3 of Volume I for details of the model.

W3(R) Vapor/gas intercept, c. This is the vapor/gas intercept used in the CCFL correlation (when $H_f^{1/2} = 0$) and must be > 0. The default value is 1.

W4(R) Slope, m. This is the slope used in the CCFL correlation and must be > 0. The default value is 1.

7.9.5 Card CCC0111, Pump Outlet (Discharge) Junction Diameter and CCFL Data

This card is optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to just specify the junction hydraulic diameter for the interphase drag calculation (i.e., f = 0 in Word 5 of Card CCC0109), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If the card is being used for the CCFL model (i.e., f = 1 in Word 5 of Card CCC0109), then enter all four words for the appropriate CCFL model if values different from the default values are desired. The format for this card is identical to Card CCC0110 except that data are for the outlet junction.

7.9.6 Card CCC0112, Pump Inlet (Suction) Junction Form Loss Data

This card is optional. The user-specified form loss coefficients are given in Words 3 and 4 of Card CCC0108 if this card is not entered. If this card is entered, the form loss coefficients depend on the flow conditions and are calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficients; A_F, A_R, B_F, B_R, C_F, and C_R are user-specified constants. A_F and A_R are Words 3 and 4 of Card CCC0108; B_F, B_R, C_F, and C_R are Words 1, 2, 3, and 4 of this card (CCC0112); and Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculations, then enter all four words for the appropriate expression.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to zero.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to zero.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to zero.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to zero.

7.9.7 Card CCC0113, Pump Outlet (Discharge) Junction Form Loss Data

This card is optional. The user-specified form loss coefficients are given in Words 3 and 4 of Cards CCC0109 if this card is not entered. If this card is entered, the form loss coefficients depend on the flow conditions and are calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficients; A_F, A_R, B_F, B_R, C_F, and C_R are user-specified constants. A_F and A_R are Words 3 and 4 of Card CCC0109; B_F, B_R, C_F, and C_R are Words 1, 2, 3, and 4 on this card (CCC0113); and Re is the Reynolds number based on mixture fluid properties. If these cards are being used for the form loss calculations, then enter all four words for the appropriate expression. The format for this card is identical to Card CCC0112 except data are for the outlet junction.

7.9.8 Card CCC0200, Pump Volume Initial Conditions

This card is required for a pump component.

W1(I) Control word. This word has the packed format $\underline{\varepsilon bt}$. It is not necessary to input leading zeros.

The digit $\underline{\varepsilon}$ specifies the fluid, where $\underline{\varepsilon} = 0$ is the default fluid. The value for $\underline{\varepsilon} > 0$ corresponds to the position number of the fluid type indicated on the 120 - 129 cards (i.e., $\underline{\varepsilon} = 1$ specifies H_2O, $\underline{\varepsilon} = 2$ specifies D_2O, etc.). The default fluid is that set for the hydrodynamic system by Cards 120 through 129 or this control word in another volume in this hydrodynamic system. The fluid type set on Cards 120 through 129 or these control words must be consistent (i.e., not specify different fluids). If Cards 120 through 129 are not entered and all control words use the default $\underline{\varepsilon} = 0$, then H_2O is assumed to be the fluid.

The digit $\underline{b}$ specifies whether boron is present or not. Entering $\underline{b} = 0$ specifies that the volume liquid does not contain boron; $\underline{b} = 1$ specifies that a boron concentration in mass of boron per mass of liquid (which may be zero) is being entered after the other required thermodynamic information.

The digit $\underline{t}$ specifies how the following words are to be used to determine the initial thermodynamic state. Entering $\underline{t}$ equal to 0 through 3 specifies one component (vapor/liquid). Entering $\underline{t}$ equal to 4, 5, 6, or 8 allows the specification of two components (vapor/liquid and noncondensable gas).

With options $\underline{t}$ equal to 4, 5, 6, or 8, the names of the components of the noncondensable gas must be entered on Card 110, and the mass fractions of the components of the noncondensable gas are entered on Card 115. Card CCC0300 may be used for the mass fractions of the components of the noncondensable gas.

If $\underline{t} = 0$, the next four words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor/gas specific internal energy (J/kg, Btu/lb_m), and vapor/gas void fraction. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the specific internal energies used to define the thermodynamic state. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 1, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 2, the next two words are interpreted as pressure (Pa, lb_f/in^2) and static quality in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in nonequilibrium or equilibrium conditions depending on the pressure and temperature used to define the thermodynamic state. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

The following options are used for input of noncondensable states. In all cases, the criteria used for determining the range of values for static quality are;

1. 1.0E-9 $\leq$ static quality $\leq$ 0.99999999, two phase conditions

2. static quality < 1.0E-9 or static quality > 0.99999999, single-phase conditions.

The static quality is given by $M_g/(M_g + M_f)$, where $M_g = M_s + M_n$. Section 3.2 of Volume I of the manual discusses this further.

Noncondensable options are as follows:

If t = 4, the next three words are interpreted as pressure (Pa, $lb_f/in.^2$), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static quality > 0.0 and $\leq$ 1.0, saturated noncondensables (100% relative humidity) will result. The temperature is restricted to be less than the saturation temperature at the input pressure and less than the critical temperature; otherwise an input error will occur. Setting static quality to 0.0 is used as a flag that will initialize the volume to all noncondensables (dry noncondensable, 0% relative humidity) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 5, the next three words are interpreted as temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. Both the static and noncondensable qualities are restricted to be between 1.0E-9 and 0.99999999. Little experience has been obtained using this option, and it has not been checked out. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If $\underline{t}$ = 6, the next five words are interpreted as pressure (Pa, $lb_f/in.^2$), liquid specific internal energy (J/kg, Btu/lb_m), vapor/gas specific internal energy (J/kg, Btu/lb_m), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the specific internal energies used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing ($\underline{t}$ = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume temperature is calculated from the noncondensable energy equation using the input vapor/gas specific internal energy. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If $\underline{t}$ = 8, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid temperature (K, ^oF), vapor/gas temperature (K, ^oF), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the temperatures used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume specific internal energy is calculated from the noncondensable energy equation using the input vapor/gas temperature. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

W2-W7(R) Quantities as described under Word 1. Depending on the control word, two through five thermodynamic quantities may be required. Enter only the minimum number required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

7.9.9 Card CCC0201, Pump Inlet (Suction) Junction Initial Conditions

This card is required for a pump component.

W1(I) Control word. If zero, the next two words are velocities; if one, the next two words are mass flow rates.

W2(R) Initial liquid velocity or initial liquid mass flow rate. This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lb_m/s), depending on the control word.

W3(R) Initial vapor/gas velocity or initial vapor/gas mass flow rate. This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lb_m/s), depending on the control word.

W4(R) Initial interface velocity (m/s, ft/s). Enter zero.

7.9.10 Card CCC0202, Pump Outlet (Discharge) Junction Initial Conditions

This card is similar to Card CCC0201 except that data are for the outlet junction.

7.9.11 Card CCC0300, Pump Volume Noncondensable Mass Fractions

This card is optional. If omitted, the noncondensable mass fractions are obtained from the noncondensable mass fractions entered on Card 115.

W1-WN(R) Mass fractions of the noncondensable species entered on Card 110. The number of words on this card should be the same as on Card 110. The sum of the noncondensable mass fractions must sum to one within a relative error of 1.0×10^{-10}.

7.9.12 Card CCC0301, Pump Index and Option

This card is required for a pump component.

W1(I) Pump table data indicator. If zero, single-phase homologous tables are entered with this component. A positive nonzero number indicates that the single-phase tables are to be obtained from the pump component with this number. If -1, built-in data for the Bingham pump. If -2, built-in data for the Westinghouse pump.

W2(I) Two-phase index. If -1, the two-phase option is not to be used. If zero, the two-phase option is desired and two-phase multiplier tables are entered with this component. If a positive nonzero number, the two-phase option is desired and the two-phase multiplier table data are to be obtained from the pump component with this number. There are no built-in data for the two-phase multiplier table.

W3(I) Two-phase difference table index. If -3, the two-phase difference table is not needed (i.e., if W2 is -1). If zero, a table is entered with this component. If a positive nonzero number, the table is to be obtained from the pump component with this number. If -1, built-in data for the Bingham pump is used. If -2, built-in data for the Westinghouse pump is used.

W4(I) Pump motor torque table index. If -1, no pump motor torque table is used. If zero, a motor torque table is entered for this pump component. If nonzero, use the motor torque table from the pump component with this number.

W5(I) Time-dependent pump rotational velocity table index. If -1, no time-dependent pump rotational velocity table is used and the pump rotational velocity is always determined by the torque-inertia equation. If zero, a rotational velocity table is entered with this component. If positive nonzero, the rotational velocity table from the pump component with this number is used. A pump rotational velocity table cannot be used when the pump is connected to a shaft control component.

W6(I) Pump motor trip number. When the pump motor trip is off, electrical power is supplied to the pump motor; when the pump motor trip is on, electrical power is disconnected from the pump motor. If the pump rotational velocity table is being used during a time step (i.e., a pump rotational velocity table has be entered in the input deck, and the pump rotational velocity table trip number is zero or the pump rotational velocity table trip number is nonzero and the pump rotational velocity table trip is on), the pump rotational velocity is computed from the pump rotational velocity table. If the pump rotational velocity table is not being used during a time step (i.e., a pump rotational velocity table has not been entered in the input deck or a pump rotational velocity table has been entered in the input deck, the pump rotational velocity table trip number is not zero, and the pump rotational velocity table trip is off), the pump rotational velocity depends on the pump motor torque data and this trip. If the motor trip is off and no pump motor torque data are present, the pump rotational velocity is the same as for the previous time step. This will be the initial pump rotational velocity if the pump trip has never been set. Usually the pump motor trip is a latched trip, but that is not necessary. If the motor trip is off and a pump motor torque table is present, the pump rotational velocity is given by the torque-inertia equation where the net torque is given by the pump motor torque data, the homologous hydraulic torque data, and the frictional torque data. If the pump motor trip is on, the torque-inertia equation is used and the pump motor torque is set to zero. If the pump motor trip number is zero, no motor trip is tested and the pump motor trip is assumed to be off.

W7(I) Reverse indicator. If zero, no reverse is allowed; if one, reverse is allowed.

7.9.13 Cards CCC0302 through CCC0304, Pump Description

This card (or cards) is required for a pump component. Words 1-12 must be entered. Words 13-17 are optional. Words 1, 9, 10, 11, 12, 13, 14, 15, 16, and 17 are used for the pump frictional torque (τ_{fr}), which is modeled as a constant or a four-term function of the pump rotational velocity and is given by

$$\tau_{fr} = \pm\tau_{frn} \qquad \text{for } \left|\frac{\omega}{\omega_R}\right| < S_{PF}$$

and

$$\tau_{fr} = \pm\left(\tau_{fr0} + \tau_{fr1}\left|\frac{\omega}{\omega_R}\right|^{x1} + \tau_{fr2}\left|\frac{\omega}{\omega_R}\right|^{x2} + \tau_{fr3}\left|\frac{\omega}{\omega_R}\right|^{x3}\right) \qquad \text{for } \left|\frac{\omega}{\omega_R}\right| \geq S_{PF}$$

where ω is the pump rotational velocity; ω_R is the rated pump rotational velocity; and τ_{frn}, τ_{fr0}, τ_{fr1}, τ_{fr2}, τ_{fr3}, x1, x2, x3, and S_{PF} (pump friction critical speed ratio) are input data. The pump frictional torque is negative if $\frac{\omega}{\omega_R} > 0$, and it is positive if $\frac{\omega}{\omega_R} < 0$.

W1(R) Rated pump velocity, ω_R (rad/s, rev/min).

W2(R) Ratio of initial pump velocity to rated pump velocity. Used for calculating initial pump velocity.

W3(R) Rated flow, Q_R (m^3/s, gal/min).

W4(R) Rated head, H_R (m, ft).

W5(R) Rated torque, τ_R (N·m, lb_f·ft).

W6(R) Moment of inertia, I_{pn} (kg·m^2, lb_m·ft^2). This includes all direct coupled rotating components, including the motor for a motor driven pump.

W7(R) Rated density, ρ_R (kg/m^3, lb_m/ft^3). If zero, initial density is used. This is the density used to generate homologous data.

W8(R) Rated pump motor torque (N·m, lb_f·ft). If this word is zero, the rated pump motor torque is computed from the initial pump velocity and the pump torque that is computed from the initial pump velocity, initial volume conditions, and the homologous curves. This quantity must be nonzero if the relative pump motor torque table is entered.

W9(R) Second frictional torque coefficient, τ_{fr2} (N·m, lb_f·ft). This parameter multiplies the absolute value of the speed ratio (pump speed/rated pump speed) to the x2 power. The frictional torque factors are summed together.

W10(R) Constant frictional torque coefficient, τ_{fr0} (N·m, lb_f·ft). This is constant frictional torque.

W11(R) First frictional torque coefficient, τ_{fr1} (N·m, lb_f·ft). This multiplies the absolute value of the speed ratio to the x1 power.

W12(R) Third frictional torque coefficient, τ_{fr3} (N·m, lb_f·ft). This multiplies the absolute value of the speed ratio to the x3 power.

W13(R) First exponent, x1. This is used on the speed ratio used with frictional torque coefficient τ_{fr1}. If zero or not entered, a default value of 1.0 is used.

W14(R) Second exponent, x2. This is used on the speed ratio used with frictional torque coefficient τ_{fr2}. If zero or not entered, a default value of 2.0 is used.

W15(R) Third exponent, x3. This is used on the speed ratio used with frictional torque coefficient τ_{fr3}. If zero or not entered, a default value of 3.0 is used.

W16(R) Pump friction torque, τ_{frn}, to be used below the pump friction critical speed ratio (N·m, lb_f·ft). If not entered, a default value of τ_{fr0} is used.

W17(R) Pump friction critical speed ratio, S_{PF}. When the absolute value of the pump speed ratio is greater than or equal to S_{PF}, the four-term expression for frictional torque is used. When the absolute value of the pump speed ratio is less than S_{PF}, the frictional torque (τ_{frn}) from Word 16 is used.

7.9.14 Card CCC0308, Pump Variable Inertia

Pump inertia is given by Word 6 of Cards CCC0302-CCC0304 if this card is not entered. If this card is entered, the pump inertia is computed from

$$I = I_{pn} \qquad \text{for} \quad \left|\frac{\omega}{\omega_R}\right| < S_{PI}$$

and

$$I = I_{p0} + I_{p1}\left|\frac{\omega}{\omega_R}\right| + I_{p2}\left|\frac{\omega}{\omega_R}\right|^2 + I_{p3}\left|\frac{\omega}{\omega_R}\right|^3 \qquad \text{for } \left|\frac{\omega}{\omega_R}\right| \geq S_{PI}$$

where ω is the pump speed, ω_R is the rated pump speed from Word 1 of Cards CCC0302-CCC0304, and I_{pn} is from Word 6 of Cards CCC0302-CCC0304. If this card in entered, all five words must be input.

W1(R) Pump inertial critical speed ratio, S_{PI}. When the absolute value of the pump speed ratio is greater than or equal to S_{PI}, the cubic expression for inertia is used. When the absolute value of the pump speed ratio is less than S_{PI}, the inertia (I_{pn}) from Word 6 of Cards CCC0302-CCC0304 is used.

W2(R) Cubic inertia coefficient, I_{p3} (kg·m^2, lb$_m$·ft^2).

W3(R) Quadratic inertia coefficient, I_{p2} (kg·m^2, lb$_m$·ft^2).

W4(R) Linear inertia coefficient, I_{p1} (kg·m^2, lb$_m$·ft^2).

W5(R) Constant inertia coefficient, I_{p0} (kg·m^2, lb$_m$·ft^2).

7.9.15 Card CCC0309, Pump-Shaft Connection

If this card is entered, the pump is connected to a SHAFT component. The pump may still be driven by a pump motor that can be described in this component, by a turbine also connected to the SHAFT component, or from torque computed by the control system and applied to the SHAFT component. The pump speed table may not be entered if this card is entered.

W1(I) Control component number of the shaft component.

W2(I) Pump-shaft disconnect trip. If this quantity is omitted or zero, the pump is always connected to the SHAFT. If nonzero, the pump is connected to the shaft when the trip is false and disconnected when the trip is true.

7.9.16 Card CCC0310, Pump Stop Data

If this card is omitted, the pump will not be stopped by the program.

W1(R) Elapsed problem time for pump stop (s).

W2(R) Maximum forward velocity for pump stop (rad/s, rev/min).

W3(R) Maximum reverse velocity for pump stop (rad/s, rev/min). Reverse velocity is a negative number.

7.9.17 Cards CCCXX00 through CCCXX99, Pump Single-Phase Homologous Curves

These cards are needed only if W1 of Card CCC0301 is zero. There are sixteen possible sets of homologous curve data to completely describe the single-phase pump operation, that is, a curve for each head and torque for each of the eight possible curve types or regimes of operation. Entering all sixteen curves is not necessary, but an error will occur from an attempt to reference one that has not been entered.

Card numbering is CCC1100 through CCC1199 for the first curve, CCC1200 through CCC1299 for the second curve, up to CCC2600 through CCC2699 for the sixteenth curve. Data for each individual curve are input on up to 100 cards, which need not be numbered consecutively.

W1(I) Curve type. Enter 1 for a head curve; enter 2 for a torque curve.

W2(I) Curve regime. See **Table 2.4-2** of this manual for definitions. The possible integer numbers and the corresponding homologous curve octants are: 1 (HAN or BAN), 2 (HVN or BVN), 3 (HAD or BAD), 4 (HVD or BVD), 5 (HAT or BAT), 6 (HVT or BVT), 7 (HAR or BAR), and 8 (HVR or BVR).

W3(R) Independent variable. Values for each curve range from -1.0 to 0.0 or from 0.0 to 1.0 inclusive. The variable is v/a for W2(I) = 1, 3, 5, or 7 and a/v for W2(I) = 2, 4, 6, or 8. If the tabular data does not span the entire range of the independent variable, end point values are used for data outside the table. This usually leads to incorrect pump performance data. Thus, entering data to cover the complete range is recommended.

W4(R) Dependent variable. The variable is h/a^2 or b/a^2 for W2(I) = 1, 3, 5, or 7 and h/v^2 or b/v^2 for W2(I) = 2, 4, 6, or 8.

Additional pairs of words corresponding to Words 3 and 4 as needed are entered on this or following cards, up to a limit of 100 pairs.

7.9.18 Cards CCCXX00 through CCCXX99, Pump Two-Phase Multiplier Tables

These cards are needed only if W2 of Card CCC0301 is zero; XX is 30 and 31 for the pump head multiplier table and the pump torque multiplier table, respectively.

W1(I) Extrapolation indicator. This is not used, enter zero.

W2(R) Void fraction.

W3(R) Head or torque difference multiplier depending on table type.

Additional pairs of data corresponding to Words 3 and 4 as needed are entered on this or additional cards, up to a limit of 100 pairs. Void fractions must be in increasing order.

7.9.19 Cards CCCXX00 through CCCXX99, Pump Two-Phase Difference Tables

These cards are required only if W3 of Card CCC0301 is zero. The two-phase difference tables are homologous curves entered in a similar manner to the single-phase homologous data.

Card numbering is CCC4100 through CCC4199 for the first curve, CCC4200 through CCC4299 for the second curve, up to CCC5600 through CCC5699 for the sixteenth curve. Data for each individual curve are input on up to 100 cards, which need not be numbered consecutively. Data are the same as the data for the single-phase data except that the dependent variable is the difference between single-phase and fully degraded two-phase data.

7.9.20 Cards CCC6001 through CCC6099, Pump Relative Motor Torque Data

These cards are required only if W4 of Card CCC0301 is zero. If the pump velocity table is not being used during a time step and these cards are present, the torque-inertia equation is used. When the electrical power is supplied to the pump motor (the pump trip is off), the net torque is computed from the rated pump motor torque times the pump relative motor torque from this table and the torque from the homologous data. If the electrical power is disconnected from the pump (the pump motor trip is on), the pump motor torque is zero.

W1(R) Pump rotational velocity (rad/s, rev/min).

W2(R) Pump relative motor torque.

Additional pairs as needed are added on this or additional cards, up to a limit of 100 pairs.

7.9.21 Card CCC6100, Pump Time-Dependent Rotational Velocity Control

This card is required only if W5 of Card CCC0301 is zero. The pump rotational velocity table, if present, has priority in setting the pump rotational velocity over the pump motor trip, the pump motor torque data, and the torque-inertia equation.

W1(I) Rotational velocity table trip number. If the trip number is zero, the pump rotational velocity is computed from this table, and the search variable is the advancement time. If the trip number is nonzero, the state of the trip determines when the table is to be used. If the trip is off, the pump rotational velocity is set from the pump motor trip (Word 6 on Card CCC0301), the pump motor torque data, and the torque-inertia equation as if this table had not been entered. If the rotational velocity table trip is on, the pump rotational velocity is computed from this table. If the rotational velocity table trip is on and Words 2 and 3 are not entered on this card, the search variable in the rotational velocity table is time, and the value of the search variable is the advancement time minus the rotational velocity table trip activation time. If this word is used, it takes precedence over the pump motor trip number used in Word 6 of the CCC0301 card.

W2(A) Alphanumeric part of variable request code. This quantity is optional. If not present, time is the search argument. If present, this word and the next are a variable request code that specifies the search argument for the table lookup and interpolation. TIME can be selected, but the trip time is not subtracted from the advancement time.

W3(I) Numeric part of variable request code. This is assumed to be zero if missing.

7.9.22 Cards CCC6101 through CCC6199, Pump Time-Dependent Rotational Velocity Data

These cards are required only if W5 of Card CCC0301 is zero.

W1(R) Search variable. Units depend on the quantity selected for the search variable.

W2(R) Pump velocity (rad/s, rev/min).

Additional pairs as needed are added on this or additional cards, up to a limit of 100 pairs. Time values must be in increasing order.

7.10 Compressor Component

A compressor component is indicated by CPRSSR for Word 2 on Card CCC0000. A compressor consists of one volume and at least one junction, attached to the inlet end of the volume. Optionally, a junction can be attached to the outlet end of the volume. For major edits, minor edits, and plot variables, the volume in the compressor component is numbered as CCC010000. The compressor junctions are numbered CCC010000 for the inlet junction and CCC020000 for the outlet junction, if it is supplied with the component.

7.10.1 Card CCC0001, Compressor Information

This card is required for a compressor component.

W1(I) Number of junctions, nj. The variable nj is the number of junctions described in the input data for this component and must be either 1 or 2. If nj = 1, then a junction is specified only at the compressor inlet. If nj = 2, then junctions are specified with the compressor component at both the inlet and the outlet. The outlet junction, if not specified with this component, can be either the inlet junction of another compressor component or a non-compressor junction.

7.10.2 Cards CCC0101 through CCC0107, Compressor Volume Geometry

This card (or cards) is required for a compressor component. The seven words can be entered on one or more cards, and the card numbers need not be consecutive.

W1(R) Volume flow area (m^2, ft^2).

W2(R) Length of volume (m, ft).

W3(R) Volume of volume (m^3, ft^3). The program requires that the volume equals the volume flow area times the length (W3 = W1•W2). At least two of the three quantities, W1, W2, W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the words are zero, the volume must equal the area times the length within a relative error of 0.000001.

W4(R) Azimuthal (horizontal) angle (degrees). The absolute value of this angle must be < 360 degrees and is defined as a positional quantity. This angle is in the horizontal x-y plane. The angle 0 degrees is on the x axis, and the angle 90 degrees is on the y axis. Positive angles are rotated from the x axis toward the y axis. This quantity is not used in the calculation but is specified for automated drawing of nodalization diagrams.

W5(R) Inclination (vertical) angle (degrees). The absolute value of this angle must be < 90 degrees. The angle 0 degrees is horizontal; positive angles have an upward direction, i.e., the outlet is at a higher elevation than the inlet. This angle is used in the interphase drag calculation and for automated drawing of nodalization diagrams. For this component, this angle is not used to decide if the horizontal or vertical flow regime is used. Rather, the high mixing flow regime map is used.

W6(R) Elevation change (m, ft). A positive value is an increase in elevation. The absolute value of this quantity must be equal to or less than the volume length. If the inclination (vertical) angle orientation is zero, this quantity must be zero. If the inclination (vertical) angle is nonzero, this quantity must also be nonzero and have the same sign. The elevation change is used in the gravity head and in checking loop closure. See Section of Volume II of the manual for further discussion. A calculated elevation angle is determined by the arcsin of the ratio of the elevation change (this word) and the volume length (Word 2). This calculated elevation angle is used in the additional stratified force term. For moving problems, see the discussion in W8. If W8 is 1 (default) or 2, this word is the position change in the fixed z direction as flow passes from the x inlet face to the x outlet face.

W7(I) Volume control flags. This word has the packed format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scaler oriented and coordinate direction oriented flags. Only one value for a scaler oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction.

At present, the f flag is the only coordinate direction oriented flag. This word enters the scaler oriented flags and the x-coordinate flag. The compressor component forces all volume flags except for the e digit, and y- and z-coordinate flags are not read. The effective format is 000000e.

The digit t is not used and must be input as zero (t = 0). Thermal stratification is not used in a compressor component.

The digit l is not used and must be entered as zero (l = 0). Level tracking is not used in a compressor component.

The digit p is not used and must be input as zero (p = 0). The major edit output will show p = 1. The water packing scheme is not used.

The digit v is not used and must be input as zero (v = 0). The major edit output will show v = 1. The vertical stratification model is not used.

The digit b is not used and must be input as zero (b = 0). The major edit will show b = 0. The rod bundle interphase friction is not used.

The digit f that normally specifies whether wall friction is to be computed is not used and a 0 must be entered. No wall friction is computed for a compressor, since it is included in the homologous compressor data. The major edit output will show f = 1, which indicates that the no friction flag is set.

The digit e specifies if nonequilibrium or equilibrium is to be used; e = 0 specifies that a nonequilibrium (unequal temperature) calculation is to be used, and e = 1 specifies that an equilibrium (equal temperature) calculation is to be used. Equilibrium volumes should not be connected to nonequilibrium volumes. The equilibrium option is provided only for comparison to other codes.

W8(I) Optional control word for elevation (or position) changes. This word is normally used only for moving problems. The elevation change in W6 is the change in the vertical direction as the flow passes from the x inlet face to the x outlet face. This is the only elevation change needed for the x coordinate for non-moving problems. For moving problems, position change information is needed in the other two horizontal directions. This control word may be 0, 1, or 2. If not entered, the default value is 1. If this word is entered as 0, the position changes for the x coordinate are computed from the x volume length (W2) and the azimuthal and inclination angles, and W6, W9, and W10 are not used. If this word is entered as 1, the position changes for the x coordinate are the elevation change (W6) for the change in the fixed z direction, from the x volume length (W2) and the azimuthal and inclination angles for the change in the fixed x and y directions, and W9 and W10 are not used. If this word is entered as 2, the position changes for the x coordinate are the elevation change (W6), W9, and W10.

W9(R) Position change in the fixed x direction as flow passes from the x inlet face to the x outlet face (m, ft). This quantity does not affect simulation results for non-moving problems. If not entered, the default value is 0.0.

W10(R) Position change in the fixed y direction as flow passes from the x inlet face to the x outlet face (m, ft). This quantity does not affect simulation results for non-moving problems. If not entered, the default value is 0.0.

7.10.3 Card CCC0108, Compressor Inlet (Suction) Junction

This card is required for a compressor component.

W1(I) Volume code of connecting volume on inlet side. This refers to the component from which the junction coordinate direction originates. An old or an expanded format can be used to connect volumes. In the old format (only allowed for connection to 1-D components), use CCC000000 if the connection is to the inlet side of the component and use CCC010000 if the connection is to the outlet side of the component. In the expanded format, the connection code for 1-D components is CCCXX000F [where CCC is the component number, XX is the volume number (greater than 00 and less than 100) for 1-D pipes/annuli/pressurizers, XX is 01 for all other 1-D components, and F indicates the face number], and the connection code for 3-D components is CCCXYYZZF (where CCC is the component number, X is the first coordinate direction position number, YY is the second coordinate direction position number, ZZ is the third coordinate direction position number, and F indicates the face number). A nonzero F specifies the expanded format. The number F equal to 1 and 2 specifies the inlet and outlet faces for the first coordinate direction, which is a 1-D volume's coordinate direction (see Section 2.1 of Volume II of this manual). The number F equal to 3 through 6 specifies crossflow for 1-D volumes. The number F equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction; F equal to 5 and 6 would do the same for the third coordinate direction. For connecting to a time-dependent volume using the old format, both CCC000000 and CCC010000 are allowed. For connecting to a time-dependent volume using the expanded format, only the number F equal to 1 or 2 is allowed. Section 4.4 in this Appendix discusses this further.

W2(R) Junction area (m^2, ft^2). If zero, the area is set to the minimum of the volume areas of adjacent volumes. If an abrupt area change, the area must be equal to or less than the minimum of the adjacent volume areas. If a smooth area change, no restrictions exist.

W3(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or zero. A variable loss coefficient may be specified (see Section 7.9.6 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W4(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. A variable loss coefficient may be specified (see Section 7.9.6 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W5(I) Junction control flags. This word has the packed format jefvcahs. It is not necessary to input leading zeros.

The digit j is not used and should be input as zero (j = 1). The jet junction model is not used.

The digit e is not used and should be input as zero (e = 0).

The digit f specifies CCFL options; f = 0 specifies that the CCFL model will not be applied, and f = 1 specifies that the CCFL model will be applied.

The digit *v* is not used and should be input as zero (v = 0). The stratification entrainment/pullthrough model is not used.

The digit c specifies choking options; c = 0 specifies that the choking model will be applied, and c = 1 specifies that the choking model will not be applied.

The digit a specifies area change options; a = 0 specifies either a smooth area change or no area change, a = 1 specifies full abrupt area change model (code-calculated K_{loss}, area apportioning at a branch, restricted junction area, and extra interphase drag), and a = 2 specifies a partial abrupt area change (no code-calculated K_{loss}, but includes area apportioning at a branch, restricted junction area, and extra interphase drag).

The digit h specifies nonhomogeneous or homogeneous; h = 0 specifies the nonhomogeneous (two-velocity momentum equations) option, and h = 1 or 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (*h* = 1 or 2), the major edit printout will show a one.

The digit s is not used and should be input as zero (s = 0).

7.10.4 Card CCC0109, Compressor Outlet (Discharge) Junction

This card is optional for a compressor component. The format for this card is identical to Card CCC0108 except data are for the outlet junction, if one is supplied with the component.

7.10.5 Card CCC0110, Compressor Inlet (Suction) Junction Diameter and CCFL Data

This card is optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to specify only the junction hydraulic diameter for the interphase drag calculation (i.e., $\underline{f}$ = 0 in Word 5 of Card CCC0108), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If the card is being used for the CCFL model (i.e., $\underline{f}$ = 1 in Word 5 of Card CCC0108), then enter all four words for the appropriate CCFL model if values different from the default values are desired.

W1(R) Junction hydraulic diameter, D_j (m, ft). This is the junction hydraulic diameter used in the CCFL correlation equation, interphase drag, and form loss Reynolds number. This number must be > 0. This number should be computed from $4.0 \bullet \left(\frac{\text{volume flow area}}{\text{wetted perimeter}}\right)$

. If a zero is entered or the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{volume flow area}}{\pi}\right)^{0.5}$. See Word 2 of Card CCC0108 for the junction area.

W2(R) Flooding correlation form, b. If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be > 0 and < 1. The default value is 0 (Wallis form). See Section 3 of Volume I for details of the model.

W3(R) Vapor/gas intercept, c. This is the vapor/gas intercept used in the CCFL correlation (when $H_f^{1/2} = 0$) and must be > 0. The default value is 1.

W4(R) Slope, m. This is the slope used in the CCFL correlation and must be > 0. The default value is 1.

7.10.6 Card CCC0111, Compressor Outlet (Discharge) Junction Diameter and CCFL Data

This card is optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to just specify the junction hydraulic diameter for the interphase drag calculation (i.e., $\underline{f}$ = 0 in Word 5 of Card CCC0109), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If the card is being used for the CCFL model (i.e., $\underline{f}$ = 1 in Word 5 of Card CCC0109), then enter all four words for the appropriate CCFL model if values different from the default values are desired. The format for this card is identical to Card CCC0110 except that data are for the outlet junction.

7.10.7 Card CCC0112, Compressor Inlet (Suction) Junction Form Loss Data

This card is optional. The user-specified form loss coefficients are given in Words 3 and 4 of Card CCC0108 if this card is not entered. If this card is entered, the form loss coefficients depend on the flow conditions and are calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficients; A_F, A_R, B_F, B_R, C_F, and C_R are user-specified constants. A_F and A_R are Words 3 and 4 of Card CCC0108; B_F, B_R, C_F, and C_R are Words 1, 2, 3, and 4 of this card (CCC0112); and Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculations, then enter all four words for the appropriate expression.

W1(R) B_F (> 0). This quantity must be greater than or equal to zero.

W2(R) C_F (> 0). This quantity must be greater than or equal to zero.

W3(R) B_R (> 0). This quantity must be greater than or equal to zero.

W4(R) C_R (> 0). This quantity must be greater than or equal to zero.

7.10.8 Card CCC0113, Compressor Outlet (Discharge) Junction Form Loss Data

This card is optional. The user-specified form loss coefficients are given in Words 3 and 4 of Cards CCC0109 if this card is not entered. If this card is entered, the form loss coefficients depend on the flow conditions and are calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficients; A_F, A_R, B_F, B_R, C_F, and C_R are user-specified constants. A_F and A_R are Words 3 and 4 of Card CCC0109; B_F, B_R, C_F, and C_R are Words 1, 2, 3, and 4 on this card (CCC0113); and Re is the Reynolds number based on mixture fluid properties. If these cards are being used for the form loss calculations, then enter all four words for the appropriate expression. The format for this card is identical to Card CCC0112 except data are for the outlet junction.

7.10.9 Card CCC0200, Compressor Volume Initial Conditions

This card is required for a compressor component.

W1(I) Control word. This word has the packed format εbt. It is not necessary to input leading zeros.

The digit ε specifies the fluid, where ε = 0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120 - 129 cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O, etc.). The default fluid is that set for the hydrodynamic system by Cards 120 through 129 or this control word in another volume in this hydrodynamic system. The fluid type set on Cards 120 through 129 or these control words must be consistent (i.e., not specify different fluids). If Cards 120 through 129 are not entered and all control words use the default ε = 0, then H_2O is assumed to be the fluid.

The digit b specifies whether boron is present or not. Entering b = 0 specifies that the volume liquid does not contain boron; b = 1 specifies that a boron concentration in mass of boron per mass of liquid (which may be zero) is being entered after the other required thermodynamic information.

The digit t specifies how the following words are to be used to determine the initial thermodynamic state. Entering t equal to 0 through 3 specifies one component (vapor/liquid). Entering t equal to 4, 5, 6, or 8 allows the specification of two components (vapor/liquid and noncondensable gas).

With options t equal to 4, 5, 6, or 8, the names of the components of the noncondensable gas must be entered on Card 110, and the mass fractions of the components of the noncondensable gas are entered on Card 115. Card CCC0300 may be used for the mass fractions of the components of the noncondensable gas.

If t = 0, the next four words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor/gas specific internal energy (J/kg, Btu/lb_m), and vapor/gas void fraction. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the specific internal energies used to define the thermodynamic state. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 1, the next two words are interpreted as temperature (K, °F) and static quality in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 2, the next two words are interpreted as pressure (Pa, lb_f/in^2) and static quality in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, °F) in nonequilibrium or equilibrium conditions depending on the pressure and temperature used to define the thermodynamic state. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

The following options are used for input of noncondensable states. In all cases, the criteria used for determining the range of values for static quality are;

1. 1.0E-9 < static quality < 0.99999999, two phase conditions

2. static quality < 1.0E-9 or static quality > 0.99999999, single-phase conditions.

The static quality is given by $M_g/(M_g + M_f)$, where $M_g = M_s + M_n$. Section 3.2 of Volume I of the manual discusses this further.

Noncondensable options are as follows:

If t = 4, the next three words are interpreted as pressure (Pa, lb_f/in^2), temperature (K, °F), and static quality in equilibrium condition. Using this input option with static quality > 0.0 and < 1.0, saturated noncondensables (100% relative humidity) will result. The temperature is restricted to be less than the saturation temperature at the input pressure and less than the critical temperature; otherwise an input error will occur. Setting static quality to 0.0 is used as a flag that will initialize the volume to all noncondensables (dry noncondensable, 0% relative humidity) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 5, the next three words are interpreted as temperature (K, °F), static quality, and noncondensable quality in equilibrium condition. Both the static and noncondensable qualities are restricted to be between 1.0E-9 and 0.99999999. Little experience has been obtained using this option, and it has not been checked out. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 6, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor/gas specific internal energy (J/kg, Btu/lb_m), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the specific internal energies used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing (t = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume temperature is calculated from the noncondensable energy equation using the input vapor/gas specific internal energy. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 8, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid temperature (K, °F), vapor/gas temperature (K, °F), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the temperatures used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume specific internal energy is calculated from the noncondensable energy equation using the input vapor/gas temperature. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

W2-W7(R) Quantities as described under Word 1. Depending on the control word, two through five thermodynamic quantities may be required. Enter only the minimum number required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

7.10.10 Card CCC0201, Compressor Inlet (Suction) Junction Initial Conditions

This card is required for a compressor component.

W1(I) Control word. If zero, the next two words are velocities; if one, the next two words are mass flow rates.

W2(R) Initial liquid velocity or initial liquid mass flow rate. This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lb_m/s), depending on the control word.

W3(R) Initial vapor/gas velocity or initial vapor/gas mass flow rate. This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lb_m/s), depending on the control word.

W4(R) Initial interface velocity (m/s, ft/s). Enter zero.

7.10.11 Card CCC0202, Compressor Outlet (Discharge) Junction Initial Conditions

This card is optional for the compressor component. This card is similar to Card CCC0201 except that data are for the outlet junction, if supplied with the compressor component.

7.10.12 Card CCC0300, Compressor Volume Noncondensable Mass Fractions

This card is optional. If omitted, the noncondensable mass fractions are obtained from the noncondensable mass fractions entered on Card 115.

W1-WN(R) Mass fractions of the noncondensable species entered on Card 110. The number of words on this card should be the same as on Card 110. The sum of the noncondensable mass fractions must sum to one within a relative error of 1.0×10^{-10}.

7.10.13 Card CCC0301, Compressor Index and Option

This card is required for a compressor component.

W1(I) Compressor performance table data indicator. If zero, compressor performance data tables are entered with this component. A positive nonzero number indicates that the data tables are to be obtained from the compressor component with this number.

W2(I) Compressor motor torque table index. If -1, no compressor motor torque table is used. If zero, a compressor motor torque table is entered for this component. If positive nonzero, use the motor torque table from the compressor component with this number.

W3(I) Time-dependent compressor rotational velocity index. If -1, no time-dependent compressor rotational velocity table is used and the compressor rotational velocity is always determined by the torque-inertia equation. If zero, a rotatonal velocity table is entered with this component. If positive nonzero, the rotational velocity table from the compressor component with this number is used. A compressor rotational velocity table cannot be used when the compressor is connected to a shaft control component.

W4(I) Compressor motor trip number. When the motor trip is off, electrical power is supplied to the compressor motor; when the motor trip is on, electrical power is disconnected from the compressor motor. If the compressor rotational velocity table is being used during a time step (i.e., a rotational velocity table has be entered in the input deck, and the compressor rotational velocity table trip number is zero or the compressor rotational velocity table trip number is nonzero and the compressor rotational velocity table trip is on), the compressor rotational velocity is computed from the compressor rotational velocity table. If the compressor rotational velocity table is not being used during a time step (i.e., a compressor rotational velocity table has not been entered in the input deck or the compressor rotational velocity table has be entered in the input deck, the compressor rotational velocity table trip number is not zero, and the compressor rotational velocity table trip is off), the compressor rotational velocity depends on the compressor motor torque data and this trip. If the motor trip is off and no compressor motor torque data are present, the compressor rotational velocity is the same as for the previous time step. This will be the initial compressor rotational velocity if the compressor trip has never been set. Usually the compressor trip is a latched trip, but that is not necessary. If the motor trip is off and a compressor motor torque table is present, the compressor rotational velocity is given by the torque-inertia equation where the net torque is given by the compressor motor torque data, the hydraulic torque from the compressor performance tables, and the frictional torque data. If the compressor motor trip is on, the torque-inertia equation is used and the compressor motor torque is set to zero. If the compressor motor trip number is zero, no motor trip is tested and the compressor motor trip is assumed to be off.

W5(I) Reverse indicator. If zero, no reverse is allowed; if one, reverse is allowed.

7.10.14 Cards CCC0302 through CCC0304, Compressor Description

This card (or cards) is required for a compressor component. Note that for the compressor component, rated values for pressure ratio and efficiency are not entered. The data for these quantities are entered directly on cards CCCXX00 through CCCXX99 ($11 \leq XX \leq 99$).

W1(R) Rated compressor rotational velocity, ω_R (rad/s, rev/min).

W2(R) Ratio of initial compressor rotational velocity to rated compressor rotational velocity. Used for calculating initial compressor rotational velocity.

W3(R) Rated compressor mass flow, $\dot{m}_R$ (kg/s, lb_m/sec).

W4(R) Rated stagnation sonic speed, $a_{0,R}$ (m/s, ft/s).

W5(R) Moment of inertia, I_{cn} (kg-m^2, lb$_m$-ft^2). This includes all direct coupled rotating components, including the motor for a motor driven compressor.

W6(R) Rated stagnation fluid density, $\rho_{0,R}$ (kg/m^3, lb$_m$/ft^3). This is the average of the fluid densities at the suction and discharge of the compressor.

W7(R) Rated compressor motor torque (N·m, lb$_f$·ft). If this word is zero, the rated compressor motor torque is computed from the initial compressor velocity and the compressor torque that is computed from the initial compressor velocity, initial volume conditions, and the torque from the compressor performance data. This quantity must be nonzero if the relative compressor motor torque table is entered.

W8(R) t_{fr2}, friction torque coefficient (N·m, lb$_f$·ft). This parameter multiplies the absolute value of the speed ratio (compressor speed/rated compressor speed) to the second power. The friction torque factors are summed together.

W9(R) t_{fr0}, friction torque coefficient (N·m, lb$_f$·ft). This is constant frictional torque.

W10(R) t_{fr1}, friction torque coefficient (N·m, lb$_f$·ft). This multiplies the absolute value of the speed ratio to the first power.

W11(R) t_{fr3}, friction torque coefficient. (N·m, lb$_f$·ft). This multiplies the absolute value of the speed ratio to the third power.

7.10.15 Card CCC0308, Compressor Variable Inertia

Compressor inertia is given by Word 5 of Card CCC0302-CCC0304 if this card is not entered. If this card is entered, compressor inertia is computed from

$$I = I_{cn} \qquad \text{for } \left|\frac{\omega}{\omega_R}\right| < S_{CI}$$

$$I = I_{c0} + I_{c1}\left|\frac{\omega}{\omega_R}\right| + I_{c2}\left|\frac{\omega}{\omega_R}\right|^2 + I_{c3}\left|\frac{\omega}{\omega_R}\right|^3 \qquad \text{for } \left|\frac{\omega}{\omega_R}\right| \geq S_{CI}$$

where ω is the compressor speed and ω_R is the rated compressor speed from Word 1 of Cards CCC0302-CCC0304, and Icn is from Word 6 of Cards CCC0302-CCC0304. If this card is entered, all five words must be input.

W1(R) Compressor inertial critical speed ratio, S_{CI}. When the absolute value of the compressor speed ratio is greater than or equal to S_{CI}, the cubic expression for inertial is used. When the absolute value of the compressor speed ratio is less than S_{CI}, the inertia (I_{cn}) from Word 6 of Card CCC0302-CCC0304 is used.

W2(R) Cubic inertial coefficient, I_{c3} ($kg{\cdot}m^2$, $lb_m{\cdot}ft^2$).

W3(R) Quadratic inertial coefficient, I_{c2} ($kg{\cdot}m^2$, $lb_m{\cdot}ft^2$).

W4(R) Linear inertial coefficient, I_{c1} ($kg{\cdot}m^2$, $lb_m{\cdot}ft^2$).

W5(R) Constant inertial coefficient, I_{c0} ($kg{\cdot}m^2$, $lb_m{\cdot}ft^2$).

7.10.16 Card CCC0309, Compressor-Shaft Connection

If this card is entered, the compressor is connected to a SHAFT component. The compressor may still be driven by a compressor motor that can be described in this component, by a turbine also connected to the SHAFT component, or from torque computed by the control system and applied to the SHAFT component. The compressor speed table may not be entered if this card is entered.

W1(I) Control component number of the shaft component.

W2(I) Compressor-shaft disconnect trip. If this quantity is omitted or zero, the compressor is always connected to the SHAFT. If nonzero, the compressor is connected to the shaft when the trip is false and disconnected when the trip is true.

7.10.17 Card CCC0310, Compressor Stop Data

If this card is omitted, the compressor will not be stopped by the program.

W1(R) Elapsed problem time for compressor stop (s).

W2(R) Maximum forward velocity for compressor stop (rad/s, rev/min).

W3(R) Maximum reverse velocity for compressor stop (rad/s, rev/min). Reverse velocity is a negative number.

7.10.18 Card CCC0401 through CCC0499, Compressor Relative Motor Torque Data

These cards are required only if W2 of Card CCC0301 is zero. If the compressor velocity table is not being used and these cards are present, the torque-inertia equation is used. When the electrical power is supplied to the compressor motor (the compressor trip is off), the net torque is computed from the rated compressor motor torque times the compressor relative motor torque from this table and the torque from the compressor performance data. If the electrical power is disconnected from the compressor (the compressor trip is on), the compressor motor torque is zero.

W1(R) Compressor rotational velocity (rad/s, rev/min).

W2(R) Compressor relative motor torque.

Additional pairs as needed are added on this or additional cards, up to a limit of 100 pairs.

7.10.19 Card CCC0500, Compressor Time-Dependent Rotational Velocity Control

This card is required only if W3 of Card CCC0301 is zero. The compressor rotational velocity table, if present, has priority in setting the compressor rotational velocity over the compressor motor trip, the compressor motor torque data, and the torque-inertia equation.

W1(I) Rotational velocity table trip number. If the table trip number is zero, the compressor rotational velocity is always computed from this table, and the search argument is the advancement time. If the table trip number is nonzero, the state of the table trip determines when the table is to be used. If the table trip is off, the compressor rotational velocity is set from the state of the compressor motor trip (Word 4 on Card CCC0301), the compressor motor torque data, and the torque-inertia equation as if this table had not been entered. If the table trip is on, the compressor rotational velocity is computed from this table. If the table trip is on and Words 2 and 3 are not entered on this card, the search variable in the table is time, and the search argument is advancement time minus the table trip activation time. If this word is used, it takes precedence over the compressor motor trip number used in Word 4 of the CCC0301 card.

W2(A) Alphanumeric part of variable request code. This quantity is optional. If not present, time is the search argument. If present, this word and the next are a variable request code that specifies the search argument for the table lookup and interpolation. TIME can be selected, but the trip activation time is not subtracted from the advancement time.

W3(I) Numeric part of variable request code. This is assumed to be zero if missing.

7.10.20 Cards CCC0501-CCC0599, Compressor Time-Dependent Rotational Velocity Data

These cards are required only if W3 of Card CCC0301 is zero.

W1(I) Search variable. Units depend on the quantity selected for the search variable.

W2(A) Compressor rotational velocity (rad/s, rev/min).

Additional pairs as necessary are added on this or additional cards, up to a limit of 100 pairs. Values of the search variable must be in increasing order.

7.10.21 Cards CCC0910-CCC0999, Compressor Relative Rotational Velocity Data

These cards are required for the compressor component. Pairs of numbers are entered. The first number of the pair is the rotational velocity relative to the rated rotational velocity specified in Word 1 of Card CCC0302. The second number is the number of triples of data (relative flow, pressure ratio, and efficiency) entered on Cards CCCXX00 through CCCXX99, which correspond to this relative rotational velocity entry.

W1(R) Relative rotational velocity.

W2(I) Number of data triples associated with this relative rotational velocity.

. . .

7.10.22 Cards CCCXX00 through CCCXX99 (10 ≤ XX ≤ 99), Compressor Performance Data.

These cards are required for the compressor component, which contain the performance data corresponding to each value of relative rotational velocity entered on cards CCC0901-CCC0999. The card numbering is CCC1000 through CCC1099 for the first data set, CCC1100 through CCC1199 for the second data set, up to a maximum of CCC9900 through CCC9999 for the 90t0h data set. The data are entered in triples, which correspond to relative corrected flowrate, pressure ratio, and efficiency.

W1(R) Relative corrected mass flowrate (kg/s, lb_m/s).

W2(R) Pressure Ratio.

W3(R) Efficiency

7.11 Multiple Junction Component

A multiple junction component is indicated by MTPLJUN for Word 2 on Card CCC0000.

The one or more junctions specified by this component can connect volumes in the same manner as several single-junction components except that all the volumes connected by the junctions in the component must be in the same hydrodynamic system. If this restriction is violated, corrective action is to merge the hydrodynamic systems. For major edits, minor edits, and plot variables, the junctions in the multiple junction component are numbered CCCIINN00, where NN is the set number and II is the junction number within the set. The quantity NN may be 01 through 99; II is 01 for the first junction described in a set and incremented by one for each additional junction (01 ≤ II ≤ 99). The quantity II does not appear as part of a card number.

7.11.1 Card CCC0001, Multiple Junction Information

This card is required.

W1(I) Number of junctions, nj. This number must be > 0 and < 100.

W2(I) Initial condition control. This word is optional and, if missing, is assumed to be zero. If zero is entered, the initial conditions on Cards CCC1NNM are velocities; if one is entered, the initial conditions are mass flow rates.

7.11.2 Cards CCC0NNM, Multiple Junction Geometry

These cards are required. Junctions are described by one or more sets of data, NN being the set number and M being the card number within a set. The junctions are numbered as CCCIINN00, where II is 01 for the first junction described in a set and increments by one for each additional junction. The quantity NN may be 01 through 99, and M may be 1 through 9. Cards are processed by increasing set number NN, and cards within a set by increasing M. Neither NN or M need be strictly consecutive.

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. An old or an expanded format can be used to connect volumes. In the old format (only allowed for connection to 1-D components), use CCC000000 if the connection is to the inlet side of the component and use CCC010000 if the connection is to the outlet side of the component. In the expanded format, the connection code for 1-D components is CCCXX000F [where CCC is the component number, XX is the volume number (greater than 00 and less than 100) for pipes/annuli/pressurizers, XX is 01 for all other 1-D components, and F indicates the face number], and the connection code for 3-D components is CCCXYYZZF [where CCC is the component number, X is the first coordinate direction (x or r) position number, YY is the second coordinate direction (y or θ) position number, ZZ is the third coordinate direction (z) position number, and F indicates the face number]. A nonzero F specifies the expanded format. The number F equal to 1 and 2 specifies the inlet and outlet faces for the first coordinate direction (x or r), which is a 1-D volume's coordinate direction (x) (see Section 2.1 of Volume II of this manual). The number F equal to 3 through 6 specifies crossflow (y or z) for 1-D volumes. The number F equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction (y or θ); F equal to 5 and 6 would do the same for the third coordinate direction (z). For connecting to a time-dependent volume using the old format, both CCC000000 and CCC010000 are allowed. For connecting to a time-dependent volume using the expanded format, only the number F equal to 1 or 2 is allowed. Section 4.4 in this Appendix discusses this further.

W2(I) To connection code to a component. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.

W3(R) Junction area (m^2, ft^2). If zero, the area is set to the minimum volume area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or smaller than the minimum of the adjoining volume areas. For smooth area changes, there are no restrictions.

W4(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or zero. A variable loss coefficient may be specified (see Section 7.11.5 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W5(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. A variable loss coefficient may be specified (see Section 7.11.5 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1). This quantity must be greater than or equal to zero.

W6(I) Junction control flags. This word has the packed format jefvcahs. It is not necessary to input leading zeros.

The digit j is not used and should be input as zero (j = 0). The jet junction model is not used.

The digit e specifies the modified PV term in the energy equations; e = 0 specifies that the modified PV term will not be applied, and e = 1 specifies that the modified PV term will be applied.

The digit f specifies CCFL options; f = 0 specifies that the CCFL model will not be applied, and f = 1 specifies that the CCFL model will be applied.

The digit v is not used and should be input as zero (v = 0). The stratification entrainment/pullthrough model is not used.

The digit c specifies choking options; c = 0 specifies that the choking model will be applied, and c = 1 specifies that the choking model will not be applied.

The digit a specifies area change options; a = 0 specifies either a smooth area change or no area change, a = 1 specifies full abrupt area change model (code-calculated K_{loss}, area apportioning at a branch, restricted junction area, and extra interphase drag), and a = 2 specifies a partial abrupt area change (no code-calculated K_{loss}, but includes area apportioning at a branch, restricted junction area, and extra interphase drag). It is recommended that the abrupt area change model (a = 1 or a = 2) be used at branches.

The digit h specifies nonhomogeneous or homogeneous; h = 0 specifies the nonhomogeneous (two-velocity momentum equations) option, and h = 1 or 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 1 or 2), the major edit printout will show h = 1.

The digit s specifies momentum flux options; s = 0 specifies momentum flux in both the to and from volume, s = 1 specifies momentum flux in the from volume but not in the to volume, s = 2 specifies momentum flux in the to volume but not in the from volume, and s = 3 specifies no momentum flux in either the to volume or the from volume.

W7(R) Subcooled discharge coefficient. This quantity is applied only to subcooled liquid choked flow calculations. The quantity must be > 0.0 and ≤ 2.0.

W8(R) Two-phase discharge coefficient. This quantity is applied only to two-phase choked flow calculations. The quantity must be > 0.0 and ≤ 2.0.

W9(R) Superheated discharge coefficient. This quantity is applied only to superheated vapor/gas choked flow calculations. The geometry must be > 0.0 and ≤ 2.0.

W10(I) From volume increment. Words 1 and 2 contain the from and to connection codes respectively for the first junction defined by the set. If the set defines more than one junction, connection codes for the following junctions are given by the connection code of the previous junction plus the increments in Words 10 and 11. The increments may be positive, negative, or zero. Words 3 through 9 apply to all junctions defined by the set. If additional sets are entered, Words 1 and 2 apply to the next junction, and increments are applied as with the first set. Word 13 for the second and following sets must be greater than Word 13 of the preceding set, and Word 13 of the last set must equal nj. Word 13 for a set is Word 13 for the previous set plus the number of junctions in the current set. Thus, W13 is the running total of the numbers of junctions currently defined for the multiple junction component. A new set is used whenever a new increment is needed, Words 3 through 9 need to be changed, or a change in junction numbering is desired.

W11(I) To volume increment. See description for Word 10.

W12(I) Enter zero. This is reserved for future capability.

W13(I) Junction limit. Described above.

7.11.3 Cards CCC1NNM, Multiple Junction Initial Condition

These cards are required. Initial velocities are entered using one or more sets of data. The processing of sets of data is identical to that described in Section 7.11.2 except that there need be no relationship in the division of junctions within sets between these cards (CCC1NNM) and the multiple junction geometry cards (CCC0NNM). Likewise, these cards do not affect the numbering of the junctions.

W1(R) Initial liquid velocity or initial liquid mass flow rate. This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lb_m/s), depending on control Word 2 of Card CCC0001.

W2(R) Initial vapor/gas velocity or initial vapor/gas mass flow rate. This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lb_m/s), depending on control Word 2 of Card CCC0001.

W3(I) Junction limit number.

7.11.4 Cards CCC2NNM, Multiple Junction Diameter and CCFL Data

These cards are optional. The defaults indicated for each word are used if the card is not entered. If the card is being used to specify only the junction hydraulic diameter for the interphase drag calculation (i.e., $\underline{f}$ = 0 in Word 6 of Cards CCC0NNM), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If this card is being used for the CCFL model (i.e., $\underline{f}$ = 1 in Word 6 of Cards CCC0NNM), then enter all four words for the appropriate CCFL model if values different from the default values are desired. The processing of sets of data is identical to that described in Section 7.11.2 except that there need be no relationship in the division of junctions within sets between these cards (CCC2NNM) and the multiple junction geometry cards (CCC0NNM). Likewise, these cards do not affect the numbering of the junctions.

W1(R) Junction hydraulic diameter, D_j (m, ft). This is the junction hydraulic diameter used in the CCFL correlation equation, interphase drag, and form loss Reynolds number. This number be $\geq$ 0. This number should be computed from $4.0 \bullet \left(\frac{\text{junction area}}{\text{wetted perimeter}}\right)$. If a zero is entered or if the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{junction area}}{\pi}\right)^{0.5}$. See Word 3 of Card CCC0NNM for junction area.

W2(R) Flooding correlation form, β. If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be $\geq$ 0 and $\leq$ 1. The default value is 0 (Wallis form). See Section 3 of Volume I for details of the model.

W3(R) Vapor/gas intercept, c. This is the vapor/gas intercept used in the CCFL correlation (when $H_f^{1/2} = 0$) and must be > 0. The default value is 1.

W4(R) Slope, m. This is the slope used in the CCFL correlation and must be > 0. The default value is 1.

W5(I) Junction limit number.

7.11.5 Card CCC3NNM, Multiple Junction Form Loss Data

These cards are optional. The processing of sets of data is identical to that described in Section 7.11.2 except that there need be no relationship in the division of junctions within sets between these cards (CCC3NNM) and the multiple junction geometry cards (CCC0NNM). Likewise, these cards do not affect the numbering of the junctions. The user-specified form loss coefficients are given in Words 4 and 5 of Card CCC0NNM if these cards are not entered. If these card are entered, the form loss coefficients depend on the flow conditions and are calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficients; A_F, A_R, B_F, B_R, C_F, and C_R are user-specified constants. A_F and A_R are Words 4 and 5 of Card CCC0NNM; B_F, B_R, C_F, and C_R are Words 1, 2, 3, and 4 on these Cards (CCC3NNM); and Re is the Reynolds number based on mixture fluid properties. If these cards are being used for the form loss calculations, then enter all five words for the appropriate expression.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to zero.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to zero.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to zero.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to zero.

W5(I) Junction limit number.

7.12 Accumulator Component

An accumulator component is indicated by ACCUM for Word 2 on Card CCC0000. For major edits, minor edits, and plot variables, the volume in the accumulator component is numbered CCC010000, and the junction in the accumulator component is numbered CCC010000.

An accumulator is a lumped parameter component treated by special numerical techniques that model the tank, tank wall, surgeline, and outlet check valve junction until the accumulator is emptied of liquid. When the last of the liquid leaves the accumulator, the code automatically resets the accumulator to an equivalent single-volume with an outlet junction and proceeds with calculations using the normal hydrodynamic solution algorithm.

In the following input requirements, it is assumed that the component is an accumulator in which liquid completely fills the surgeline but may or may not occupy the tank. It is further assumed that the accumulator is not initially in the injection mode. Hence, the initial pressure must be input lower than the injection point pressure, including elevation head effects; and junction initial conditions may not be input (i.e., initial hydrodynamic velocities are set to zero in the code). It is further assumed that the noncondensable gas in the accumulator is nitrogen (nitrogen must be one of the noncondensable gas types specified on Card 110) and that the gas, vapor, and liquid are initially in equilibrium. No other junctions (except the accumulator junction) should be connected to the accumulator volume. The geometry of the tank may be cylindrical or spherical. The standpipe/surgeline inlet refers to the end of the pipe inside the tank itself (see Section 2.4.13).

7.12.1 Cards CCC0101 through CCC0109, Accumulator Volume Geometry

These cards are required.

W1(R) Volume flow area (m^2, ft^2). This is the flow area of a cylindrical tank, or the maximum flow area of a spherical tank. In the case of a spherical tank, the maximum flow area and the tank radius are related by the formula $A = \pi R^2$.

W2(R) Length of volume (m, ft). This is the length of the tank above the standpipe/surgeline inlet, where this inlet refers to the end of the pipe inside the tank itself.

W3(R) Volume of volume (m^3, ft^3). This is the volume of the tank above the standpipe/surgeline inlet, where this inlet refers to the end of the pipe inside the tank itself. The code requires that the volume, volume flow area, and length are consistent. For a cylindrical tank, W3 = W1•W2, and at least two of the three quantities, W1, W2 or W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. For a spherical tank, W1 and W2 must be nonzero. If W3 is zero, it will be computed from the other two. If none of the words are zero, they must satisfy the consistency condition within a relative error $\pm$ 0.000001.

W4(R) Azimuthal (horizontal) angle (degrees). The absolute value of this angle must be $\leq$ 360 degrees and is defined as a positional quantity. This angle is in the horizontal x-y plane. The angle 0 degrees is on the x axis, and the angle 90 degrees is on the y axis. Positive angles are rotated from the x axis toward the y axis. This quantity is not used in the calculation but is specified for automated drawing of nodalization diagrams.

W5(R) Inclination (vertical) angle (degrees). Only +90 or -90 degrees is allowed. The accumulator is assumed to be a vertical tank with the standpipe/surgeline inlet (where this inlet refers to the end of the pipe inside the tank itself) at the bottom. This angle is used in the interphase drag calculation and for automated drawing of nodalization diagrams. As with other components, this angle is used to decide if the horizontal or vertical flow regime map is used. This is not important for this component, since the correlations that depend on the flow regime map are not needed for this component. The volume conditions are determined from the accumulator's special model.

W6(R) Elevation change (m, ft). This is the elevation change from the standpipe/surgeline inlet (where this inlet refers to the end of the pipe inside the tank itself) to the top of the tank. A positive value is an increase in elevation. The absolute value of this quantity must be nonzero, less than or equal to the volume length, and have the same sign as the inclination (vertical) angle. The elevation change is used in the gravity head and in checking loop closure. See Section 2.4.1 of Volume II of the manual for further discussion. A calculated elevation angle is determined by the arcsin of the ratio of the elevation change (this word) and the volume length (Word 2). This calculated elevation angle is used in the additional force term.

W7(R) Wall roughness (m, ft). The wall roughness is limited to be greater than or equal to 1.0×10^{-9} times the hydraulic diameter. If zero, the wall roughness is computed from 1.0×10^{-9} times the hydraulic diameter.

W8(R) Hydraulic diameter (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{volume flow area}}{\text{wetted perimeter}}\right)$. If zero, the hydraulic diameter of the tank is computed from $2.0 \bullet \left(\frac{\text{volume flow area}}{\pi}\right)^{0.5}$.

A check is made that the pipe roughness is less than half the hydraulic diameter of the tank. See Word 1 for the volume flow area.

W9(I) Volume control flags. This word has the packed format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scaler oriented and coordinate direction oriented flags. Only one value for a scaler oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. This word enters the scaler oriented flags and the x-coordinate flag. The accumulator component forces all volume flags except for the x-coordinate f digit, and y- and z-coordinate flags are not read. The effective format is 00110f0 where 0 and 1 indicate fields as set by the accumulator component. The user must enter 0 in the digits marked with 0 and may enter 0 or 1 in the digits marked with 1.

The t digit is not used and must be set to 0. The thermal stratification model is not used for an accumulator component.

The l digit is not used and must be set to 0. The level tracking model is not used for an accumulator component.

The digit p is not used and may be input as 0 or 1. The major edit will show p = 1. The water packing scheme is not used.

The digit v is not used and may be input as 0 or 1. The major edit will show v = 1. The vertical stratification model is not used.

The digit b is not used and must be input as zero. The rod bundle interphase friction model is not used.

The digit f specifies whether wall friction is to be computed; f = 0 specifies that wall friction effects are to be computed along the x-coordinate; f = 1 specifies friction effects are not to be computed along the x-coordinate.

The flag e must be specified zero, since only a nonequilibrium (unequal temperature) calculation is allowed.

W10(I) Geometry flag (optional). To specify a cylindrical tank, set the flag equal to 0 (default); to specify a spherical tank, set the flag equal to 1.

7.12.2 Card CCC0131, Accumulator Additional Wall Friction

This card is optional. If this card is not entered, the default values are 1.0 for the laminar shape factor and 0.0 for the viscosity ratio exponent. Two quantities must be entered on the card. A description of this input is presented in Section 3 of Volume I. The accumulator model automatically does not use the following words as long as liquid remains in the accumulator. However, when the accumulator empties of liquid, the model is automatically converted to an active normal volume. The following words are then used as defined.

W1(R) Shape factor.

W2(R) Viscosity ratio exponent.

7.12.3 Card CCC0141, Accumulator Alternate Turbulent Wall Friction

This card is optional. THis card allows the specification of a user-defined turbulent friction factor. The turbulent friction factor has the form $f = A + B(Re)^{-C}$, where A, B, and C are entered for the accumulator volume. If this card is not entered, the standard turbulent friction factor is used. If the card is entered, the standard turbulent friction factor can be selected by entering zeros for the three quantities. Three quantities must be entered on the card. The accumulator model automatically does not use the following words as long as liquid remains in the accumulator. However, when the accumulator empties of liquid, the model is automatically converted to an active normal volume. The following words are then used as defined.

W1(R) A.

W2(R) B.

W3(R) C.

7.12.4 Card CCC0200, Accumulator Tank Initial Thermodynamics Conditions

This card is required.

W1(R) Pressure (Pa, lb_f/in^2).

W2(R) Temperature (K, ^oF).

W3(R) Boron concentration (mass of boron per mass of liquid). This word is optional.

7.12.5 Card CCC1101, Accumulator Junction Geometry

This card is required.

W1(I) To connection code to a component. This refers to the component from which the junction coordinate direction originates. An old or an expanded format can be used to connect volumes. In the old format (only allowed for connection to 1-D components), use CCC000000 if the connection is to the inlet side of the component and use CCC010000 if the connection is to the outlet side of the component. In the expanded format, the connection code for 1-D components is CCCXX000F [where CCC is the component number, XX is the volume number (greater than 00 and less than 100) for pipes/annuli/pressurizers, XX is 01 for all other 1-D componets, and F indicates the face number]. A nonzero F specifies the expanded format. The number F equal to 1 and 2 specifies the inlet and outlet faces for the first coordinate direction, which is a 1-D volume's coordinate direction (see Section 2.1 of Volume II of this manual). The number F equal to 3 through 6 specifies crossflow for 1-D volumes. The number F equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction; F equal to 5 and 6 would do the same for the third coordinate direction. For connecting to a time-dependent volume using the old format, both CCC000000 and CCC010000 are allowed. For connecting to a time-dependent volume using the expanded format, only the number F equal to 1 or 2 is allowed. Section 4.4 in this Appendix discusses this further.

W2(R) Junction area (m^2, ft). This is the average area of the surgeline and standpipe.

W3(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or zero. The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W4(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W5(I) Junction control flags. This word has the packed format jefvcahs. It is not necessary to input leading zeros. The accumulator model automatically disables the following flags as long as liquid remains in the accumulator. However, when the accumulator empties of liquid, the model is automatically converted to an active normal volume. The following flags are then enabled and used as defined.

The digit j is not used and should be input as zero (j = 0). The jet junction model is not used.

The digit e is not used and should be input as zero (e = 0). The modified PV term in the energy equation is not used.

The digit f is not used and should be input as zero (f = 0). The CCFL model is not used.

The digit v is not used and should be input as zero (v = 0). The stratification entrainment/pullthrough model is not used.

The digit c specifies choking options; c = 0 specifies that the choking model will be applied, and c = 1 specifies the choking model will not be applied.

The digit a specifies area change options; a = 0 specifies either a smooth area change or no area change, and a = 1 or 2 is not allowed for an accumulator.

The digit h specifies nonhomogeneous or homogeneous; h = 0 specifies the nonhomogeneous (two-velocity momentum equations) option, and h = 1 or 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 1 or 2), the major edit will show h = 1.

The digit s specifies momentum flux options; s = 0 specifies momentum flux in both the to volume and the from volume, s = 1 specifies momentum flux in the from volume but not in the to volume, and s = 2 or 3 is not allowed for an accumulator.

7.12.6 Card CCC1102, Accumulator Form Loss Data

This card is optional. The user-specified form loss coefficients are given in Words 3 and 4 of Card CCC1101 if this card is not entered. If this card is entered, the form loss coefficients depend on the flow conditions and are calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse loss coefficients: A_F, A_R, B_F, B_R, C_F, and C_R are user-specified constants. A_F and A_R are Words 3 and 4 of Card CCC1101, B_F, B_R, C_F, C_R are Words 1, 2, 3, and 4 of this card (CCC1102): and Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculations, then enter all four words for the appropriate expression. The accumulator model automatically does not use the following words as long as liquid remains in the accumulator. However, when the accumulator empties of liquid, the model is automatically converted to an active normal volume. The following words are then used as defined.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to zero).

W2(R) B_R (≥ 0). This quantity must be greater than or equal to zero).

W3(R) C_F (≥ 0). This quantity must be greater than or equal to zero).

W4(R) C_R (≥ 0). This quantity must be greater than or equal to zero).

7.12.7 Card CCC2200, Accumulator Tank Initial Fill Conditions, Standpipe/Surgeline Length/Elevation, and Tank Wall Heat Transfer Terms

This card is required.

W1(R) Liquid volume in tank (m^3, ft^3). This is the volume of liquid contained in the tank above the standpipe/surgeline inlet (where this inlet refers to the end of the pipe inside the tank).

W2(R) Liquid level in tank (m, ft). This is the liquid level contained in the tank above the standpipe/surgeline inlet (where this inlet refers to the end of the pipe inside the tank) entrance. For a cylindrical tank, either W1 or W2 must be specified as nonzero. For a spherical tank, W2 must be specified as nonzero. If one of the words is zero, it is computed from the other two.

W3(R) Length of surgeline and standpipe (m, ft). If input as zero, then the surgeline and standpipe are not modeled.

W4(R) Elevation drop of surgeline and standpipe (m, ft). This is the elevation drop from the standpipe/surgeline inlet (where this inlet refers to the end of the pipe inside the tank) entrance to the injection point. A positive number denotes a decrease in elevation.

W5(R) Tank wall thickness (m, ft). This is not allowed to be zero.

W6(I) Heat transfer flag. If zero, heat transfer will be calculated. If one, no heat transfer will be calculated.

W7(R) Tank density (kg/m^3, lb_m/ft^3). If zero, the density will default to that for carbon steel.

W8(R) Tank specific heat capacity ($J/kg \bullet K$, $Btu/lb_m \bullet {}^oF$). If zero, the specific heat capacity will default to that for carbon steel.

W9(I) Trip number. If zero or if no number is input, then no trip test is performed. If nonzero then this must be a valid trip number, the operations performed are similar to those performed for a trip valve. If the trip is false, then the accumulator is isolated and no flow through the junction can occur. If the trip is true, then the accumulator is not isolated and flow through the junction will occur in the normal manner for an accumulator.

At least 11 words must be entered on these cards, and 16 words may be entered. Words 12 through 16 specify mass fractions for the noncondensable species entered on Card 110. Five quantities must be entered for Words 12 through 16 (if more than 11 words are entered), and zeros should be entered for species not present in the volumes. The noncondensable mass fractions must sum to one within a relative error of 1.0×10^{-10}. If Words 12 through 16 are omitted, the noncondensable mass fractions are obtained from the noncondensable mass fractions entered on Card 115.

For $\underline{v}$ = 1 or 2, the horizontal volume flow area must be greater than or equal to the offtake volume flow area.

8 Cards 1CCCGXNN, Heat Structure Input

These cards are used in NEW and RESTART type problems and are required only if heat structures are described. The heat structure card numbers are divided into fields, where

CCC is a heat structure number. The heat structure numbers need not be consecutive. We suggest, but the system does not require, that if heat structures and hydrodynamic volumes are related, they be given the same number.

G is a geometry number. The combination CCCG is a heat structure geometry combination referenced in the heat structure input data. The G digit is provided to differentiate between different types of heat structures (such as fuel pins and core barrel) that might be associated with the same hydrodynamic volume.

X is the card type.

NN is the card number within a card type.

8.1 Card 1CCCG000, General Heat Structure Data

This card is required for heat structures. Use eight words for new data input or one word for deleting a heat structure.

8.1.1 General Heat Structure Data

W1(I) Number of axial heat structures with this geometry, nh. This number must be > 0 and < 100.

W2(I) Number of radial mesh points for this geometry, np. This number must be < 100. Enter > 1 if no reflood is specified, and > 2 if reflood or metal water reaction is specified.

W3(I) Geometry type. Enter 1 or -1 for rectangular, 2 or -2 for cylindrical, and 3 or -3 for spherical. A positive value indicates the heat structure is coupled to the hydrodynamic components. A negative value indicates that the heat structure is decoupled from the hydrodynamic components. Decoupling means that the heat structure responds to the hydraulic conditions in the hydrodynamic volumes to which it is attached, but the energy removed from (or added to) the surface of the heat structure by convection is not added to (or removed from) the hydrodynamic volumes. Spherical geometry is not allowed if reflood is specified. Cylindrical geometry must be specified when the gap conductance model is used.

W4(I) Steady-state initialization flag. Use zero if the desired initial condition temperatures are entered on input Cards 1CCCG401 through 1CCCG499; use one if the steady-state initial condition temperatures are to be calculated by the code. If option one is chosen, the user is still required to enter temperatures on Cards 1CCCG401 through 1CCCG499. In this case, the temperatures are used as starting points for the steady-state solutions. The user should therefore enter temperatures either below or above the minimum film boiling point to assure the respective pre-DNB or post-DNB steady-state condition is calculated. This is because the boiling curve is multi-valued.

W5(R) Left boundary coordinate (m, ft). The left boundary coordinate must be less than the right boundary coordinate because the mesh intervals must be positive. This is discussed further in Section 3.1 of Volume II of the manual.

W6(I) Reflood condition flag. This quantity is optional if no reflood calculation is to be performed. This quantity may be 0, 1, 2, or a trip number. If zero, no reflood calculation is to be performed. If nonzero, a reflood calculation is to be performed and all the heat structures in this heat structure/geometry are assumed to form a two-dimensional representation of a fuel pin. The radial mesh is defined on Card 1CCCG1NN. Each heat structure represents an axial level of the fuel pin, with the first heat structure being the bottom level. Each heat structure should be connected to a hydrodynamic volume representing the same axial section of the coolant channel. The length of the axial mesh in the fuel pin is given by the length of the connected hydrodynamic volume. If the heat structure is fuel pins or heat exchanger tubes, the length factor (Word 5 on Cards 1CCCG501 through 1CCCG599 and Cards 1CCCG601 through 1CCCG699) is the product of the hydrodynamic volume length and the number of pins or tubes (see Volume II, Section 3.2). The heat structures represent the temperatures at the midpoint of the axial mesh. Once the reflood calculation is initiated, additional mesh lines are introduced at each end of the fuel pin and between the heat structures. Once the reflood calculation is initiated, it remains activated, and the two-dimensional heat conduction calculation uses a minimum of $2 \bullet nh + 1$ axial mesh nodes. Additional mesh lines are introduced and later eliminated as needed to follow the quench front. If 1 is entered, the reflood calculation is initiated in this heat structure geometry when the average pressure in the connected hydrodynamic volumes is less than 1.2×10^6 Pa (174.045288 lb_f/in^2 if British input is used), and the average void fraction in the interconnected hydrodynamic volumes is greater than 0.9 (i.e., nearly empty). If 2 is entered, the reflood calculation is initiated in this heat structure geometry when the average pressure in the connected hydrodynamic volumes is less than 1.2×10^6 Pa (174.045288 lb_f/in^2 if British input is used) and the average void fraction in the interconnected hydrodynamic volumes is greater than 0.1 (i.e., dryout begins). If a trip number is entered, the reflood calculation is initiated when the trip is set true. When using the expanded trip number format, 1 and 2 are possible trip numbers. A 1 or 2 entered in this word is not treated as a trip number.

W7(I) Boundary volume indicator. This word is only used is a reflood calculation is to be performed (Word 6 is nonzero). This word is optional if no reflood calculation is to be performed. Enter zero or one to indicate that reflood heat transfer applies to the left or right boundary, respectively.

W8(I) Maximum number of axial intervals. This word is only used if a reflood calculation is to be performed (Word 6 is nonzero). This word is optional if no reflood calculation is to be performed. Enter 2, 4, 8, 16, 32, 64, or 128 to indicate the maximum number of axial subdivisions a heat structure can have. Storage is allocated for the number indicated, even though a transient may not require that level of subdivision. Recommendations are discussed in Volume II, Section 3.6.

8.1.2 Heat Structure Delete

This card is entered only for RESTART problems. If entered, all heat structures associated with the heat structure geometry number CCCG are deleted. The heat structures should not be changed for RESTART problems, either by the addition of a new heat structure or by the deletion of an existing heat structure, if the radiation/ conduction enclosure model has been used in the original run.

W1(A) Enter DELETE.

8.2 Card 1CCCG001, Gap Conductance Model Initial Gap Pressure Data

This card is needed only if the gap conductance model is to be used. If the card is entered, Word 1 of Card 1CCCG100 must be zero, Cards 1CCCG011 through 1CCCG099 are required, and Cards 1CCCG201 through 1CCCG299 are required. Word 2 of Card 201MMM00 must be 3, and a table of the gas component name and mole fraction must be specified in the gap material data (Cards 201MMM01 through 201MMM49). In addition, the right boundary condition Cards 1CCCG601 through 1CCCG699 must have a hydrodynamic volume specified in Word 1.

At this time, only one gap is allowed with only one material allowed on each side of the gap (represents fuel and cladding).

W1(R) Initial gap internal pressure (Pa, lb_f/in^2).

W2(I) Gap conductance reference volume. This word is required. The pressure of the gas in a fuel pin for the gap conductance model is given by $P(t) = [P(0)/T(0)] \bullet T(t)$, where t is time, P(t) is the pressure in the fuel pin at time t, and T(t) is the temperature in the reference volume at time t. P(0) is Word 1 above, and T(0) is the initial value, if the volume is also being defined with these input data or the value from the restart block. The reference volume is usually the hydrodynamic volume [i.e., the nine-digit number CCCXX0000 (for 1-D volumes)] most closely associated with the nonfuel region in a fuel pin at the top of a stack of fuel pellets.

8.3 Card 1CCCG003, Metal-Water Reaction Control

CCCG is a heat structure geometry number. If this card is not present, no metal-water reaction will be calculated. The initial oxide thickness is assumed to be zero on the inner surface. It remains zero unless cladding rupture occurs.

W1(R) Initial oxide thickness on cladding's outer surface (m, ft).

8.4 Card 1CCCG004, Fuel Cladding Deformation Model Control

CCCG is a heat structure geometry number. If this card is not present, no cladding deformation calculations will be done. If this card is present, then Card 1CCCG001 must also be present.

W1(I) Form loss factor flag. Enter 0 if no additional form loss factors are to be calculated after a rod ruptures. Enter 1 if additional form loss factors are to be calculated. Either a 0 or a 1 must be entered.

8.5 Cards 1CCCG011 through 1CCCG099, Gap Deformation Data

These cards are required for the gap conductance model only. The card format is sequential format, five words per set, describing nh heat structures.

W1(R) Fuel surface roughness (m, ft). This number must be $\geq$ 0. An appropriate value is 1.0 x 10^{-6} m (or 3.280839895 x 10^{-6} ft if British input is used). A negative entry is reset to 1.0 x 10^{-6} m (or 3.280839895 x 10^{-6} ft if British input is used) with no errors.

W2(R) Cladding surface roughness (m, ft). This number must be either positive or zero. An appropriate value is 2 x 10^{-6} m (or 6.561679790 x 10^{-6} ft if British input is used). A negative entry is reset to 2 x 10^{-6} m (or 6.561679790 x 10^{-6} ft if British input is used) with no errors.

W3(R) Radial displacement due to fission gas-induced fuel swelling and densification (m, ft). This number must be $\geq$ 0. A negative entry is reset to zero. An appropriate value can be obtained from calculations using FRAPCON-2 or FRAP-T6.

W4(R) Radial displacement due to cladding creepdown (m, ft). The value is normally negative. A positive entry is reset to zero. An appropriate value can be obtained from calculations using FRAPCON-2 or FRAP-T6.

W5(I) Heat structure number.

8.6 Card 1CCCG100, Heat Structure Mesh Flags

This card is required for heat structure input.

W1(I) Mesh location flag. If zero, geometry data, including mesh interval data, composition data, and source distribution data, are entered with this heat structure input. If nonzero, that information is taken from the geometry data from the heat structure geometry (CCCG) number in this word. If this word is nonzero, the remaining geometry information described in Section 8.7 through Section 8.9 is not entered.

W2(I) Mesh format flag. This word is needed only if Word 1 is zero, though no error occurs if it is present when Word 1 is nonzero. The mesh interval data are given as a sequence of pairs of numbers in one of two formats to be used in Cards 1CCCG101 through 1CCCG199. If this word is 1 (Format 1 on Cards 1CCCG101 through 1CCCG199), the pairs of numbers contain the number of intervals in this region and the right boundary coordinate. For the first pair, the left coordinate of the region is the left boundary coordinate previously entered in Word 5 of Card 1CCCG000; for succeeding pairs, the left coordinate is the right coordinate of the previous pair. For the last pair, the right coordinate of this region is the right boundary coordinate. If this word is 2 (Format 2 on Cards 1CCCG101 through 1CCCG199), the format is a sequential expansion of mesh intervals; i.e., the distance in Word 1 on Cards 1CCCG101 through 1CCCG199 is used for each interval starting from the leftmost, as yet unspecified, interval to and including the interval number specified in Word 2.

8.7 Cards 1CCCG101 through 1CCCG199, Heat Structure Mesh Interval Data (Radial)

These cards are required if Word 1 of Card 1CCCG100 is zero. In Format 1 (Word 2 of Card 1CCCG100 is 1), the sum of the numbers of intervals must be np-1. In Format 2 (Word 2 of Card 1CCCG100 is 2), the sequential expansion must be for np-1 intervals. The card numbers need not be sequential.

8.7.1 Format 1 (Word 2 of Card 1CCCG100 is 1)

W1(I) Number of intervals. Enter the number of intervals, not the interval number.

W2(R) Right coordinate (m, ft).

8.7.2 Format 2 (Word 2 of Card 1CCCG100 is 2)

W1(R) Mesh interval (m, ft).

W2(I) Interval number.

8.8 Cards 1CCCG201 through 1CCCG299, Heat Structure Composition Data (Radial)

These cards are required if Word 1 of Card 1CCCG100 is zero and must not be entered otherwise. The card format is two numbers per set in sequential expansion format for np-1 intervals. The card numbers need not be in sequential order.

W1(I) Composition number. The absolute value of this quantity is the composition number, and it must be identical to the subfield MMM used in Heat Structure Thermal Property Data, Section 10, Cards 201MMMNN. The user may select built-in thermal properties or supply a table/function. The sign indicates whether the region over which this composition is applied is to be included or excluded from the heat structure volume averaged temperature computation. If positive, the region is included; if negative, the region is not included. The option to exclude regions from the volume averaged temperature integration is to limit the integration to fuel regions only for use in reactivity feedback calculations. Gap and cladding regions should not be included in this case. If the gap conductance model is used, only one interval can be used for the gap model.

W2(I) Interval number.

8.9 Cards 1CCCG301 through 1CCCG399, Heat Structure Source Distribution Data (Radial)

These cards are required if Word 1 of Card 1CCCG100 is zero and must not be entered otherwise. The card format is two numbers per set in sequential expansion format for np-1 intervals. The card numbers need not be in sequential order. Radial power peaking factors are entered here for the internal volumetric heat source (See Section 3.1 of this volume of the manual).

W1(R) Source value $Q_{i,input}$. These are relative values only and can be scaled by any non-zero factor without changing the results (See Volume II, Section 3.1). By entering different values for the various mesh intervals, a characteristic shape of a power curve can be described. If all the source variables are zero, there will be no internal heat generation for the heat structure geometry.

W2(I) Mesh interval number.

8.10 Card 1CCCG400, Initial Temperature Flag

This card is optional; if missing, Word 1 is assumed to be zero.

W1(I) Initial temperature flag. If this word is zero or -1, initial temperatures are entered with the input data for this heat structure geometry. If greater than zero, initial temperatures for this heat structure geometry are taken from the heat structure geometry number in this word, and the initial temperature distribution from Section 8.11 is not needed.

8.11 Cards 1CCCG401 through 1CCCG499, Initial Temperature Data

These cards are required if Word 1 of Card 1CCCG400 is zero or -1.

8.11.1 Format 1 (Word 1 on Card 1CCCG400 = 0)

If Word 1 of Card 1CCCG400 is zero, one temperature distribution is entered; and the same distribution is applied to all of the nh heat structures. The card format is two numbers per set in sequential expansion format for np mesh points.

W1(R) Temperature (K, ^{o}F).

W2(I) Mesh point number.

8.11.2 Format 2 (Word 1 on Card 1CCCG400 = -1)

If Word 1 of Card 1CCCG400 is -1, a separate temperature distribution must be entered for each of the nh heat structures. The distribution for the first heat structure is entered on Card 1CCCG401, the distribution for the second heat structure is entered on Card 1CCCG402, and the remaining distributions are entered on consecutive card numbers. Continuation cards can be used if the data do not fit on one card.

W1-WNP(R) Temperature (K, ^{o}F). Enter the np mesh point temperatures in order from left to right.

8.12 Cards 1CCCG501 through 1CCCG599, Left Boundary Condition

These cards are required. The boundary condition data for the heat structures with this geometry are entered in a slightly modified form of sequential expansion using six quantities per set for the number of heat structures with this geometry (nh sets). The modification deals with Words 1 and 2.

The left boundary condition cards may specify the fluid volumes to which the heat structure is connected, and the heat transfer surface areas. In addition, these cards allow the user to implement, using a table or control variable, an absolute boundary condition such as a surface temperature, surface heat flux, or heat transfer coefficient. See Section 4.1 of Volume I of the manual for a discussion of the boundary condition equation. See Section 3.2 of Volume II of the manual for a table and discussion that summarizes the various boundary condition types (Word 3) that are possible for the several Word 1 options. See Section 4.7.3 of Volume V of the manual for a discussion of the various boundary conditions.

W1(I) Boundary condition (i.e., sink temperature) definition, which can be described by a boundary volume indicator, a general table temperature, a control variable that calculates the temperature, or the number zero. The sink temperature is discussed in Volume I, Section 4.1 of the manual. The use of interactive variables to calculate the temperature is not allowed.

If a **volume number** is input for Word 1, this word specifies the hydrodynamic volume indicator {of the form CCCXX000F for 1-D components [CCC is the component number and XX is the volume number (greater than 00 and less than 100) for 1-D pipes/annuli/pressurizers, XX is 01 for all other 1-D components]}. A boundary volume indicator is entered as a positive number. If F is 0 or 4, the volume coordinate associated values used in the wall heat transfer correlations, such as the phasic velocities (used in the mass flux) and the volume hydraulic diameter [used in the heat transfer hydraulic diameter (heated equivalent diamteer)] are taken from the first coordinate direction (x for 1-D volumes, x or r for 3-D volumes); if F is 2, the volume coordinate associated values used in the wall heat transfer correlations are taken from the second coordinate direction (y for 1-D volumes, y or θ for 3-D volumes); if F is 1, the volume coordinate associated values used in the wall heat transfer correlations are taken from the third coordinate direction (z for 1-D volumes, z for 3-D volumes). Specifying a volume coordinate not is use (no junctions attached to either volume face in the coordinate direction) is an input error. The user should note that the values of F used here are different than the values of F used in the volume minor edit/plot requests (Section 4.4 , Appendix A, Volume II) and the connection codes for junction components (Section 2.1, Volume II and Section 7, Appendix A, Volume II).

If a **general table** is input for Word 1, it must be of the type TEMP (temperature versus time). A general table is entered as a negative number (-1 through -999), where the table number is the absolute value of Word 1.

If a **control variable** is input for Word 1, it is entered as a negative number (-10001 through -19999), where the control variable is the absolute value of Word 1 minus 10000.

If the **number zero** is input for Word 1, a non-convective boundary condition [radiation/conduction heat flux boundary condition or a symetry/insulated boundary condition (i.e., a zero temterature gradient at the boundary)] is used if Word 3 is zero; a temperature of zero is used for a surface temperature in the boundary conditions (also a temperature of zero is used for a sink temperature in the boundary conditions) is used if Word 3 is 1000; and a temperature of zero is used for a sink temperature in the boundary conditions if Word 3 is 1xxx, 2xxx, 3xxx, or 4xxx.

W2(I) Increment. This word and Word 1 of this card are treated differently from the standard sequential expansion. Word 1 of the first set applies to the first heat structure of the heat structure geometry set. The increment (normally 10000 for boundary volume) is added to Word 1, which results in the hydraulic volume number associated with heat structure 2; etc. The increment is applied up to the limit in Word 6 of a set. Word 1 of the next set applies to the next heat structure, and increments are applied as for the first set. The increment may be zero or nonzero, positive or negative. If Word 1 is zero or negative, this word should be zero. Additional examples are shown in Section 4 of Volume V.

W3(I) Boundary condition type. See Section 3.2 of Volume II of the manual for a table that summarizes the various boundary condition types (Word 3) that are possible for the various Word 1 options. A radiation/conduction enclosure heat flux may be included on any surface. A surface having a specified temperature or specified heat flux flux boundary condition may be included in a radiation/conduction enclosure but the surface heat flux computed by the radiation/conduction enclosure model will not affect the temperature distribution in the heat structure.

If 0, a non-convective boundary condition is used (a radiation/conduction enclosure heat flux boundary condition or a symmetry/insulated boundary condition). If the surface is included in a radiation/conduction enclosure, the heat flux on the surface in computed by that model. If the surface is not included in a radiation/conduction enclosure, a symmetry or insulated boundary surface is assumed and a zero flux boundary condition is used (i.e., a zero temperature gradient is used at the boundary). The boundary volume number (Word 1) must be 0.

If 1 or 1nn, a convective boundary condition where the total wall heat transfer coefficient obtained from Wall Heat Transfer Package 1 is used. The allowed values of 1nn are shown in **Table 8.12-1**. Volumes I and IV discuss the partitioning and the sink temperature used for this option. Word 1 must specify a boundary volume number with this boundary condition type. Generally, the hydrodynamic volume will not be a time dependent volume. Caution should be used in specifying a time dependent volume, since the elevation and length are set to zero, and the velocities in an isolated time dependent volume will be zero. Note that the current version of the code does not allow an isolated standard volume or an isolated time dependent volume. If reflood is specified (reflood is only allowed for the right side of a heat structure), the boundary condition type must be the same for all nh heat structures.

There are several numbers allowed for Word 3 to activate convective boundary conditions for nonstandard geometries. A 1, 100, or 101 give the default values. The numbers 1, 100, and 101 use the same correlations. The number 101 is recommended; the numbers 1 and 100 are allowed so that the code is backwards compatible with previous input decks. The default convection, boiling, and condensation correlations were derived mainly based on data from internal vertical pipe flow. Other possible input values are shown in **Table 8.12-1**. When modeling a vertical bundle, the rod or tube pitch-to-diameter ratio should be input on the 1CCCG901 through 1CCCG999 cards. This has the effect of increasing the convective part of wall heat transfer such that users can input the true heat transfer hydraulic diameter and get reasonable predictions.

Table 8.12-1 Cards 1CCCG501 through 1CCCG599 and 1CCCG601 through 1CCCG699, Word 3, convection boundary type.

Word 3	Geometry Type
1, 100, 101	Default
102	Vertical parallel plates [ORNL, ANS reactor; set pitch (gap) and span on CCC3101 through CCC3199 hydro cards for pipes and CCC0111 hydro card for single volumes and branches, set b = 2 in volume control flag on CCC1001 through CCC1099 hydro cards for pipes and CCC0101 through CCC0109 hydro cards for single volumes and branches]
110	Vertical bundle without crossflow (set P/D on 1CCCG801 through 1CCCG899 and 1CCCG901 through 1CCCG999 heat slab cards)
111	Vertical bundle with crossflow (set P/D on 1CCCG801 through 1CCCG899 and 1CCCG901 through 1CCCG999 heat slab cards)
115	Swirl tubes
130	Flat plate above fluid
134	Horizontal bundle
151	Vertical aluminum annulus (SRL)
160	Gnielinski for forced convection in a tube
161	Bishop for forced convection in a tube
162	Koshizuka-Oka for forced convection in a tube
163	Jackson for forced convection in a tube
164	Jackson for forced/mixed convection in a tube (upflow)
165	Jackson for forced/mixed convection is a tube (downflow)

If 1000, the volume fraction averaged temperature of the boundary volume (as specified in Word 1) [i.e., void fraction (α_g) times vapor/gas temperature (T_g) plus liquid fraction (α_f) times liquid temperature (T_f)] is used as the left surface temperature if a boundary volume is present. The temperature from the general table or control variable (as specified in Word 1) is used as the left surface temperature if a boundary volume is not present. If Word 1 is zero, the left surface temperature is set to zero. This option is not allowed for reflood. This option is generally used to support efforts to analyze experimental data and does not contain all the physics present in the boundary condition option (1 or 1nn) that uses the wall heat transfer correlations.

If 1xxx, the temperature as a function of time from general table xxx is used as the left surface temperature. The general table xxx input in Word 3 must be of the type TEMP (temperature versus time). This option is not allowed for reflood. This option is generally used to support efforts to analyze experimental data and does not contain all the physics present in the boundary condition option (1 or 1nn) that uses the wall heat transfer correlations.

If 2xxx, the total wall heat flux as a function of time from general table xxx is used as the left boundary condition. The general table xxx input in Word 3 must be of the type HTRNRATE (heat flux versus time). The partitioning for this option, when a boundary volume is present, is that the wall-to-vapor/gas wall heat flux is given by the void fraction (α_g) times the table total wall heat flux and the wall-to-liquid wall heat flux is given by the liquid volume fraction (α_f) times the table total wall heat flux. The partitioning for this option, when a boundary volume is not present, is that the wall-to-vapor/gas wall heat flux is given by half the table total wall heat flux and the liquid wall-to-liquid wall heat flux is given by half the table total wall heat flux. If reflood is specified, the boundary condition type must be the same for all nh heat structures. This option is generally used to support efforts to analyze experimental data and does not contain all the physics present in the boundary condition option (1 or 1nn) that uses the wall heat transfer correlations. The user needs to use caution when using the wall heat flux boundary condition. If the heat flux is too large (positive or negative), a numerical failure may result.

If 3xxx, the total wall heat transfer coefficient as a function of time from general table xxx is used as the left boundary condition. The general table xxx input in Word 3 must be of the type HTC-T (heat transfer coefficient versus time). The partitioning for this option, when a boundary volume is present, is that the wall-to-vapor/gas wall heat transfer coefficient is given by the void fraction (α_g) times the table total wall heat transfer coefficient and the wall-to-liquid wall heat transfer coefficient is given by the liquid volume fraction (α_f) times the table total wall heat transfer coefficient. When a boundary volume is present, the sink temperature is the volume fraction averaged fluid temperature of the boundary volume [i.e., void fraction (α_g) times vapor/gas temperature (T_g) plus liquid fraction (α_f) times liquid temperature (T_f)]. The partitioning for this option, when a boundary volume is not present, is that the wall-to-vapor/gas wall heat transfer coefficient is given by half the table total wall heat transfer coefficient and the wall-to-liquid wall heat transfer coefficient is given by half the table total wall heat transfer coefficient. When a boundary volume is not present, the sink temperature is from the general table or control variable (as specified in Word 1) or set to zero if Word 1 is zero. If reflood is specified, the boundary condition type must be the same for all nh heat structures. This option is generally used to support efforts to analyze experimental data and does not contain all the physics present in the boundary condition option (1 or 1nn) that uses the wall heat transfer correlations.

If 4xxx, the total wall heat transfer coefficient as a function of surface temperature from general table xxx is used as the left boundary condition. The general table xxx input in Word 3 must be of type HTC-TEMP (heat transfer coefficient versus temperature). The partitioning for this option, when a boundary volume is present, is that the wall-to-vapor/gas wall heat transfer coefficient is given by the void fraction (α_g) times the table total wall heat transfer coefficient and the wall-to-liquid wall heat transfer coefficient is given by the liquid volume fraction (α_f) times the table total wall heat transfer coefficient. When a boundary volume is present, the sink temperature is the volume fraction averaged fluid temperature of the boundary volume [i.e., void fraction (α_g) times vapor/gas temperature (T_g) plus liquid fraction (α_f) times liquid temperature (T_f)]. The partitioning for this option, when a boundary volume is not present, is that the wall-to-vapor/gas wall heat transfer coefficient is given by half the table total wall heat transfer coefficient and the wall-to-liquid wall heat transfer coefficient is given by half the table total wall heat transfer coefficient. When a boundary volume is not present, the sink temperature is from the general table or control variable (as specified in Word 1) or set to zero if Word 1 is zero. If reflood is specified, the boundary condition type must be the same for all nh heat structures. This option is generally used to support efforts to analyze experimental data and does not contain all the physics present in the boundary condition option (1 or 1nn) that uses the wall heat transfer correlations.

W4(I) Surface area code. If zero, Word 5 is the left surface area. If one, Word 5 is (a) the surface area in rectangular geometry, (b) the cylinder length or equivalent in cylindrical geometry, or (c) multiplier factor which is a fraction of a sphere (0.5 is a hemisphere) in spherical geometry.

W5(R) Surface area, length, or multiplicative factor. For Word 4 equal to zero, this word specifies surface area for any geometry. For Word 4 equal to one, this word specifies surface area for rectangular geometry (m^2, ft^2), length for cylindrical geometry (m, ft), or multiplicative factor for spherical geometry (dimensionless). For the meaning of length for cylindrical geometry, see Volume II, Section 3.2. If the symmetry boundary condition is specified (Word 3 = 0), this word must still be entered nonzero. The left and right surface areas (or factors) must be consistent. This is discussed in Volume II, Section 3.2.

W6(I) Heat structure number.

8.13 Cards 1CCCG601 through 1CCCG699, Right Boundary Condition

These cards are required. These cards are the same as Cards 1CCCG501 through 1CCCG599, except for the right boundary. The left and right surface areas must be compatible with the geometry. NOTE: Boundary condition type for a feedwater heater component heat structure should be specified as a horizontal bunble (Word 3 = 134).

8.14 Cards 1CCCG701 through 1CCCG799, Source Data

These cards are required for heat structure data. The card format is sequential expansion format, five words per set, describing nh heat structures.

W1(I) Power source type. If zero, no source is used. If a positive number is less than 1000, power from the general table with this number is used as the source. If 1000 through 1004, the number has the form 100t, and the source is taken from a point kinetics calculation. The field t = 0 specifies total reactor power (fission power, fission product decay power, and actinide decay power), t = 1 specifies total decay (fission product and actinide) power, t = 2 specifies fission power, t = 3 specifies fission product decay power, and t = 4 specifies actinide decay power. If 10001 through 19999, the source is the control variable whose number is this quantity minus 10000.

W2(R) Internal source multiplier, P_f. This value is multiplied by the power in the power source specified in Word 1 to obtain the power generated in the heat structure. This factor is not a relative factor (See Volume II, Section 3.1).

W3(R) Direct moderator heating multiplier for left boundary volume (see Volume II, Section 3.3). This value is multiplied by the power in the power source specified in Word 1 to obtain the power deposited directly into the left boundary volume.

W4(R) Direct moderator heating multiplier for right boundary volume (see Volume II, Section 3.3). This value is multiplied by the power in the power source specified in Word 1 to obtain the power deposited directly into the right boundary volume.

W5(I) Heat structure number.

8.15 Card 1CCCG800, Additional Left Boundary Option

W1(I) If this card is not entered or if this word is zero, the nine-word format is used on Cards 1CCCG801 through 1CCCG899. If this word is 1, the twelve-word format is used on the cards. If this word is 2, the thirteen-word format is used on the cards (needed for the PG-CHF correlation). If this word is 10 or 11, the Osmachkin CHF correlation (for RBMK analysis) is used. The nine-word format is used on the cards if this word is 10, and the twelve-word format is used on the cards if this word is 11. If this word is 3, the fourteen-word format is used on the cards (needed for the ITER heat transfer model).

8.16 Cards 1CCCG801 through 1CCCG899, Additional Left Boundary

These cards are required whenever the left boundary communicates energy with a fluid volume. The cards are in sequential expansion format (nine words per set if nine-word format, twelve words per set if twelve-word format, thirteen words per set if thirteen-word format, fourteen words per set if fourteen-word format), describing nh heat structures. Sequential expansion would only be used where the critical heat flux value was not of importance, since the length to all heat structures in the expansion would be the same. Words 2 through 8 for the nine-word, twelve-word, thirteen-word, and fourteen-word formats, Word 12 in the thirteen word format, and Words 12 and 13 in the fourteen-word format are used for the CHF correlations.

Nine-word format (Card 1CCCG800 not entered or Word 1 = 0 on Card 1CCCG800).

W1(R) Heat transfer hydraulic diameter (i.e., heated equivalent diameter) (m, ft). This is $4\left(\frac{\text{flow area}}{\text{heated perimeter}}\right)$ and is recommended to be greater than or equal to the volume hydraulic diameter since (heated perimeter) $\leq$ (wetted perimeter). It is possible to input this diameter to be less than the volume hydraulic diameter. If Word 1 equals 0.0, the volume hydraulic diameter is used. See Section 3.5 of Volume II of the manual for further guidelines.

W2(R) Heated length forward (m, ft). Distance is from the heated inlet to the center of this slab. This quantity will be used when the liquid volume velocity is positive or zero. This is used to get the hydraulic entrance length effect. This is used only for the Groeneveld CHF correlation. It must be > 0. To ignore the length effect, put in a large number (i.e., $\geq$ 10.0).

W3(R) Heated length reverse (m, ft). Distance is from the heated outlet to the center of this slab. This quantity will be used when the liquid volume velocity is negative. This is used to get the hydraulic entrance length effect. This is used only for the Groeneveld CHF correlation. It must be > 0. To ignore the length effect, put in a large number (i.e., $\geq$ 10.0).

W4(R) Grid spacer length forward (m, ft). Distance is from the center of this slab to the nearest grid or obstruction upstream. This quantity will be used when the liquid volume velocity is positive or zero. This is used to get the boundary layer disturbance and atomization effect of a grid spacer in rod bundles. This is used only for the Groeneveld CHF correlation. If the grid K loss (Word 6) is zero, Word 4 is not used.

W5(R) Grid spacer length reverse (m, ft). Distance is from the center of the slab to the nearest grid or obstruction downstream. This quantity will be used when the liquid volume velocity is negative. This is used to get the boundary layer disturbance and atomization effect of a grid spacer in rod bundles. This is used only for the Groeneveld CHF correlation. If the grid K loss (Word 7) is zero, Word 5 is not used.

W6(R) Grid loss coefficient forward. Used for forward flow in rod bundles. This quantity is used when the liquid volume velocity is positive or zero. This is used only for Groeneveld CHF calculation.

W7(R) Grid loss coefficient reverse. Used for reverse flow in rod bundles. This quantity is used when the liquid volume velocity is negative. This is used only for the Groeneveld CHF correlation.

W8(R) Local boiling factor. Enter 1.0 if there is no power source in the heat structure or if the local equilibrium quality is negative (i.e., liquid is subcooled and void fraction is zero). This is the local heat flux/average heat flux from start of boiling. If the power profile is not flat, a steady-state run may help determine this number. This number must be greater than 0.0.

W9(I) Heat structure number.

Twelve-word format (Word 1 = 1 on Card 1CCCG800). The first eight words of this format are identical to the first eight words of the nine-word format.

W9(R) Natural circulation length (m, ft). This should be the height of a hydraulic natural convection cell. For a heated vertical plate, this is the total height of the plate. For inside a horizontal tube, this should be the inside tube diameter. For the outer surface of vertical or horizontal bundles, it is suggested to use the heated bundle height in the vertical direction. When using the nine-word format or when using this twelve-word format with this word set to 0.0, this quantity is set to the value of Word 1, the heat transfer hydraulic diameter (i.e., heated equivalent diameter).

W10(R) Rod or tube pitch-to-diameter ratio. The pitch is the distance between the centers of adjacent rods or tubes. The diameter is the diameter of the rod or tube. The minimum allowed value is 1.1. The maximum allowed value is 1.6. When using the nine-word format, this quantity is set to 1.1.

W11(R) Fouling factor. This factor multiplies the wall heat transfer coefficients and may be used to represent fouling or to run sensitivity studies. This quantity must be a positive nonzero number. When using the nine-word format, this quantity is set to 1.0.

W12(I) Heat structure number.

Thirteen-word format for PG-CHF (Word 1 = 2 on Card 1CCCG800). Set Word 1 = 0. Words 9, 10, and 11 of this format are identical to Words 9, 10, and 11 of the twelve-word format.

W2(R) Reduced heated length forward (m, ft). This is the product $(y \bullet T_a)$. The first term is the distance from the heated channel inlet to the point of the predicted CHFR when the liquid volume velocity is positive or zero. The second term is the ratio of average heat flux from the heated channel inlet to the axial coordinate y (m, ft), i.e., at the point of the predicted CHFR, to local heat flux q at y. Word 2 should be determined as follows:

$$y \bullet T_a = \frac{1.}{q(y)} \int_0^y q(z)dz .$$

W3(R) Reduced heated length reverse (m, ft). This is the product $(y \bullet T_a)$. The first term is the distance from the heated channel outlet to the point of the predicted CHFR when the liquid volume velocity is negative. The second term is the ratio of average heat flux from the heated channel outlet to the axial coordinate y (m, ft), i.e., at the point of the predicted CHFR, to local heat flux q at y. Word 3 should be determined as follows:

$$y \bullet T_a = \frac{1.}{q(y)} \int_0^y q(z)dz .$$

W4(R) Grid spacer factor forward. This should be input as follows:

If Word 12 = 11, 12, 21, 22, 31, 32, 41, or 42, i.e., CHFR for the tube or the internally heated annulus, then Word 4 must be input as W4 = 1.0.

If Word 12 = 13, 23, 33, or 43, i.e., CHFR for the rod bundle with <u>vaneless</u> grid spacers, then Word 4 should be input either as W4 = 1.0 / $\overline{R}$, if the statistical evaluation data for the rod bundles are available ($\overline{R}$ is the mean of variable R. R is the statistical random variable representing CHFR, i.e., predicted CHF to measured CHF ratio), or as W4 = 1.0, if the statistical evaluation data for the rod bundle are not available.

If Word 12 = 14, 24, 34, or 44, i.e., CHFR for the rod bundle with <u>vane</u> grid spacers, then Word 4 should be input as: W4 could be determined from statistical evaluation data of specific fuel design.

If Word 12 = 15, then W4 should be input as W4 = 1.0.

W5(R) Grid spacer factor reverse. This should be input as follows:

If Word 12 = 11, 12, 21, 22, 31, 32, 41, or 42, i.e., CHFR for the tube or the internally heated annulus, then Word 5 must be input as W5 = 1.0.

If Word 12 = 13, 23, 33, or 43, i.e., CHFR for the rod bundle with vaneless grid spacers, then Word 5 should be input either as W5 = 1.0 / $\overline{R}$, if the statistical evaluation data for the rod bundles are available ($\overline{R}$ is the mean of variable R. R is the statistical random variable representing CHFR, i.e., predicted CHF to measured CHF ratio), or as W5 = 1.0, if the statistical evaluation data for the rod bundle are not available.

If Word 12 = 14, 24, 34, or 44, i.e., CHFR for the rod bundle with vane grid spacers, then Word 5 should be input as: W5 could be determined from statistical evaluation data of specific fuel design.

If Word 12 = 15, then W5 should be input as W5 = 1.0.

W6(R) Factor of the radial heat flux distribution. This should be input as:

$$T_r = q\frac{\sum_i r_i}{\sum_i r_i q_i}$$

This is the ratio of local heat flux on referred perimeter to average heat flux on perimeters pertaining to the subchannel (or the annulus).

W7(I) Heated channel upstream hydrodynamic volume number. The volume number is of the form CCCXX0000. This refers to the hydrodynamic volume which represents the inlet for the heated channel. This is to get the heated channel inlet quality in the case of forward flow direction.

W8(I) Heated channel downstream hydrodynamic volume number. The volume number is of the form CCCXX0000. This refers to the hydrodynamic volume which represents the outlet for the heated channel. This is to get the heated channel inlet quantity in the case of flow in the reverse direction.

W12(I) CHFR correlation option. This is input in mn format. The first digit specifies the CHFR correlation form.

If m = 1, then the basic form of PG CHFR correlation is used.

If m = 2, then the flux form of the PG CHFR correlation is used.

If m = 3, then the geometry form of PG CHFR correlation is used.

If m = 4, then the power form of PG CHFR correlation is used.

The second digit specifies the geometry of heated structure. If this is the rod bundle, it specifies if and how the statistical evaluation data are applied for the grid spacer factor (see Word 4 and Word 5).

If n = 1, then this is the tube.

If n = 2, then this is the internally heated annulus.

If n = 3, then this is the rod bundle. The use of an isolated subchannel model is recommended. This is used if the applicable PG CHFR correlation statistical evaluation data are not available.

If n = 4, then this is the rod bundle. The use of an isolated subchannel model is recommended. An extended use of the PG CHFR statistical evaluation data is enabled.

If n = 5, then this is the rod bundle. This is only used in combination with m = 1. Applicable for a subchannel code respecting lateral mixing.

W13(I) Heat structure number.

Fourteen-word format (Word 1 = 3 on Card 1CCCG800). Words 1 through 11 are identical to the twelve-word format.

W12(R) Swirl tube twist ratio. If Word 12 = 0.0, the code will reset the twist ratio to 200.0, which is equivalent to modeling a bare tube.

W13(R) Swirl tube inner diameter. If Word 13 = 0.0, the heat transfer hydraulic diameter (i.e., heated equivalent diameter) (Word 1) is used.

W14(I) Heat structure number.

8.17 Card 1CCCG900, Additional Right Boundary Option

This card is the same as Card 1CCCG800 but applies to the right boundary. However, an additional value for Word 1 applies to the right boundary of heat structures associated with the FWHTR component. Word 1 equal to 4 indicates a thirteen-word format for cards 1CCCG901-1CCCG999 (needed for additional FWHTR heat structure right boundary data).

8.18 Cards 1CCCG901 through 1CCCG999, Additional

Right Boundary

These cards are the same as Cards 1CCCG801 through 1CCCG899 but apply to the right boundary. However if Word 1 equals 4 on card 1CCCG900, indicating right boundary data for a FWHTR heat structure, the 9^{th}, 10^{th}, 11^{th}, and 12^{th} words on these cards are as follows:

Thirteen-word format for FWHTR (Word 1 = 4 on Card 1CCCG900). Word 1 through 8 are identical to Words 1 through 8 of the nine-word format. The natural circulation length (Word 9 in the twelve-word format) and the rod or tube pitch-to-diameter ratio (Word 10 in the twelve-word format) are set to their nine-word format default values (the value of Word 1 and and a value of 1.1, respectively).

W9(R) Bottom non-dimensional length defined as the ratio of the distance between the bottom of the FWHTR shell and the bottom of the heat structure (variable L_1 in Volume IV of the manual) divided by the hydraulic diameter of the right boundary volume. This number must be greater than or equal to zero. When using the nine-word format, this quantity is set to 0.2.

W10(R) Top non-dimensional length defined as the ratio of the distance between the bottom of the FWHTR shell and the top of the heat structure (variable L_2 in Volume IV of the manual) divided by the hydraulic diameter of the right boundary volume. This number must be greater than or equal to zero. When using the nine-word format, this quantity is set to 0.8.

W11(R) Number of tubes in vertical alignment represented by this heat structure. This is variable n in Volume IV of the manual. Guidance on setting this number is given in Section 4.6.6.5 of Volume V of the manual. This number must be greater than zero. When using the nine-word format, this quantity is set to 20.

W12(R) Fouling factor. This factor multiplies the wall heat transfer coefficients and may be used to represent fouling or to run sensitivity studies. This quantity must be a positive nonzero number. When using the nine-word format, this quantity is set to 1.0.

W13(I) Heat structure number.

9 Cards 6SSNNXXX, Radiation/Conduction Enclosure Input

These cards are used in NEW and RESTART type problems. This means that the radiation/conduction enclosures may be changed during a restart. This also means the heat structures may be renodalized on restart (i.e., add a new heat structure, delete an existing heat structure, or replace an existing heat structure) if the radiation/conduction enclosure model is activated in the original run. Heat structures need to be input (Cards 1CCCGXNN) in order to use these cards.

9.1 Card 60000000, Radiation/Conduction Enclosure Model Control

Any heat structure may radiate/conduct to any other heat structure or set of heat structures in a user-defined enclosure. An enclosure is a set of heat structures that communicate via thermal radiation/conduction. The calculation ignores fluid in the enclosure.

This card is required.

W1(I) Number of sets of radiation/conduction enclosures, nset. This word must be less than 100 and greater than 0 for radiation/conduction to be on.

9.2 Card 6SS00000, Radiation/Conduction Enclosure Set

SS is the set number. One of these cards must be input for each radiation/conduction enclosure set. One can specify whether the set is radiating or conducting by the sign of Word 1 of this card. For radiation, Word 1 is required and must be positive; Words 2, 3, and 4 are optional. For conduction, Word 1 is required and must be negative; Words 2, 3, and 4 are not used.

This card is required.

W1(I) Number of radiation/conduction enclosure heat slabs, nrh. This word is required. If positive, radiation input is assumed. If negative, conduction input is assumed. This word is the number of radiation/conduction enclosure heat slabs (surfaces) that participate in radiation/conduction enclosure heat transfer in set SS. The maximum is 99.

W2(R) Minimum surface temperature, trmin (K, ^{o}F). If input, this word is the minimum surface temperature below which radiation will no longer be calculated. Each radiation surface in the set is checked, and if any have a surface temperature greater than Word 2, radiation is computed in the enclosure set. The default value is 900 K (1,160.33 ^{o}F). This limit only applies to a radiation enclosure, and the conduction enclosure model is always active.

W3(R) Minimum void fraction, voidmn. If input, this word is the minimum void fraction below which radiation will no longer be calculated. Each volume connected to any of the radiating surfaces in the set is checked, and if any have a void fraction greater than Word

3, radiation is computed in the enclosure set. The default value is 0.75. This limit only applies to a radiation enclosure, and the conduction enclosure model is always active.

W4(I) View factor set, refset. If input, this is the number of the set (SS) from which view factors are to be obtained. If no number is found here, the view factors must be input for this set. This word only applies to a radiation enclosure; it is not used for a conduction enclosure model.

9.3 Card 6SSNN001, Radiation/Conduction Enclosure Heat Structure Data

For this card, SS (set number) must take on every value from 1 to nset (Word 1 in Card 60000000), and NN (surface number) must take on every value from 1 to absolute value of nrh (Word 1 on Card 6SS00000) for each SS. Data are entered for each surface that participates in radiation/conduction enclosure heat transfer.

This card is required.

W1(I) Heat structure geometry level, jrh. This word is CCCG0ZZ, where CCCG is the heat structure geometry combination of nh, and ZZ is the axial level number participating in radiation/conduction enclosure heat transfer.

W2(I) Surface flag, jlr. For this word, 0 = left surface, and 1 = right surface of NN.

W3(R) For a radiation enclosure [positive nrh (Word 1 on Card 6SS000000)], this is the emissivity of surface NN. For a conduction enclosure [negative nrh (Word 1 on Card 6SS000000)], this is the gap conductance ($W/m^2 \bullet K$, $Btu/s \bullet ft^2 \bullet {}^oF$) between surface number NN and the other heat structures within set number SS that surface number NN is in contact with. If this gap conductance is not available, the textbook harmonic mean formula is recommended, where the gap conductance is given by $k_1 k_2 / [(k_1 + k_2) dl]$ and k_1, k_2 are the thermal conductivities ($W/m \bullet K$, $Btu/s \bullet ft \bullet {}^oF$) of the two surfaces and dl is the gap distance (m, ft) between the two surfaces.

9.4 Cards 6SSNN101 through 6SSNN199, Radiation/Conduction Enclosure View/Area Factors

There are nrh•nrh values in each set, where nrh is Word 1 on Card 6SS000000. SS is the set number [from 1 to nset (Word 1 on Card 60000000)]. NN is the surface number [from 1 to absolute value of nrh (Word 1 on Card 6SS00000)]. For a given NN, the sum of the view factors must be 1.0 within a relative error of 0.001 for the radiation enclosure model. For the conduction enclosure model, the area factors represent the portion of the surfaces conducting to the other surfaces, so it is not necessary that the sum of the area factors be 1.0 within a relative error of 0.001. For the radiation/conduction enclosure model, the view/area factor times the surface area of surface NN must equal the view/area factor times the area of the receiving surface withi a realtive eroor of 0.001.

This card is required.

W1(R) View factor, vfij. View factor from surface NN to surface W2(I). For the conduction enclosure model, this is the fraction of the surface area of heat structure NN in touch with surface W2(I).

W2(I) Radiation/conduction enclosure surface number to which surface number NN radiates/conducts. Repeat the above two words until view factors to all nrh (Word 1 on Card 6SS00000) surfaces from all surfaces are entered. Sequential expansion is used for the radiation enclosure model.

10 Cards 201MMMNN, Heat Structure Thermal Property Data

These cards are used in NEW or RESTART problems. These cards are required if Cards 1CCCGXNN, Heat Structure Input Cards, Section 8 are entered. These data, if present, are processed and stored even if no Cards 1CCCGXNN are entered.

The subfield MMM is the composition number, and the cards with this subfield describe the thermal properties of composition MMM. The composition numbers entered on Cards 1CCCG201 through 1CCCG299 correspond to this subfield. A set of Cards 201MMMNN must be entered for each composition number used, but MMM need not be consecutive. During RESTART, thermal property may be deleted, new compositions may be added, or data may be modified by entering new data for an existing composition.

10.1 Card 201MMM00, Composition Type and Data Format

This card is required.

W1(A) Material type. Thermal properties for five materials are stored within the program: gap (GAP), carbon steel (C-STEEL), stainless steel (S-STEEL), uranium dioxide (UO2), and zircaloy (ZR). These properties are selected by entering the name in parentheses for this word. These stored (built-in) properties are discussed further in Volume I, Section 4.5 and Volume V, Section 4.7.5. The user should check whether the data are satisfactory. If a user-supplied table or function is to be used, enter TBL/FCTN for this word. The word DELETE may be entered in RESTART problems to delete a composition.

The next two words are required only if TBL/FCTN is entered for W1.

W2(I) Thermal conductivity format flag or gap mole fraction flag. Enter 1 if a table containing temperature and thermal conductivity is to be entered. Enter 1 if a constant thermal conductivity is to be entered using Word 1 on Card 201MMM01. Enter 2 if functions are to be entered. Enter 3 if the gap conductance model is used, and thus a table containing gas component names and mole fractions is to be entered.

W3(I) Volumetric heat capacity format flag. Enter 1 if a table containing temperature and volumetric heat capacity is to be entered. Enter 1 if a constant volumetric heat capacity is to be entered using Word 1 on Card 201MMM51. Enter -1 if a table containing only volumetric heat capacities is to be entered and the temperature values are identical to the thermal conductivity table. Enter 2 if functions are to be entered.

10.2 Cards 201MMM01 through 201MMM49, Thermal Conductivity

Data or Gap Mole Fraction Data

These cards are required if W1 of Card 201MMM00 contains TBL/FCTN. For a table, enter pairs of temperatures and thermal conductivities or pairs of gas component names and mole fractions according to the specification of W2 of Card 201MMM00. For the gap conductance model, the code will calculate the thermal conductivity. One to 7 pairs of gas names and their mole fractions can be entered. The gas component names that may be entered are HELIUM, ARGON, KRYPTON, XENON, NITROGEN, HYDROGEN, and OXYGEN. No particular order of the pairs is required. Do not enter any gas component with a zero mole fraction. Normalization of the total mole fraction to one is performed if the sum of the mole fractions entered is not one. The table of gas composition data is required if Card 1CCCG001 is present.

10.2.1 Table Format

If only one word is entered, that word contains the thermal conductivity and it is assumed constant. Otherwise, pairs of temperatures and thermal conductivities are entered. The number of pairs is limited to 100. The temperatures must be in increasing order. The end-point temperatures must bracket the expected temperatures during the transient. That is, if the temperature is outside the bracketed range, a failure will occur, and a diagnostic edit will be printed out.

W1(R) Temperature (K, ^{o}F) or gas name. The allowed gas names are HELUIM, ARGON, KRYPTON, XENON, NITROGEN, HYDROGEN, and OXYGEN.

W2(R) Thermal conductivity (W/m•K, Btu/s•ft•^{o}F) or mole fraction.

10.2.2 Functional Format

In the functional format, sets of nine quantities are entered, each set containing one function and its range of application. The function is

$$k = A_0 + A_1(TX) + A_2(TX)^2 + A_3(TX)^3 + A_4(TX)^4 + A_5(TX)^{-1}$$

where TX = T - C, T is the temperature argument, and C is a constant. Each function has a lower and upper limit of application. The first function entered must be for the lowest temperature range. The lower limit of each following function must equal the upper bound of the previous function.

W1(R) Lower limit temperature (K, ^{o}F).

W2(R) Upper limit temperature (K, ^{o}F).

W3(R) A_0 (W/m•K, Btu/s•ft•^{o}F).

W4(R) A_1 (W/m•K^2, Btu/s•ft•$^oF^2$).

W5(R) A_2 (W/m•K^3, Btu/s•ft•$^oF^3$).

W6(R) A_3 (W/m•K^4, Btu/s•ft•$^oF^4$).

W7(R) A_4 (W/m•K^5, Btu/s•ft•$^oF^5$).

W8(R) A_5 (W/m, Btu/s•ft).

W9(R) C (K, ^oF).

10.3 Cards 201MMM51 through 201MMM99, Volumetric Heat Capacity Data

These cards are required if W1 of Card 201MMM00 contains TBL/FCTN. The card numbers need not be consecutive.

10.3.1 Table Format

If only one word is entered, that word contains the volumetric heat capacity and it is assumed constant. Pairs of temperature and volumetric heat capacity are entered if the temperatures are different than the temperatures in the thermal conductivity table or if functions are used for thermal conductivity. If the temperature values are identical, only the volumetric heat capacities need be entered. The number of pairs or single entries are limited to 100. The temperatures must be in increasing order. The end-point temperatures must bracket the expected temperatures during the transient. That is, if the temperature is outside the bracketed range, a failure will occur, and a diagnostic edit will be printed out.

W1(R) Temperature (K, ^oF). If only volumetric heat capacities are being entered, a volumetric heat capacity is entered here rather than a temperature.

W2(R) Volumetric heat capacity (J/m^3·K, Btu/ft^3·^oF). This is ρC_p, where ρ is density (kg/m^3, lb_m/ft^3) and C_p is specific heat capacity (J/kg·K, Btu/lb_m·^oF).

10.3.2 Functional Format

In the functional format, sets of nine quantities are entered, each set containing one function and its range of application. The function is

$$\rho C_p = A_0 + A_1(TX) + A_2(TX)^2 + A_3(TX)^3 + A_4(TX)^4 + A_5(TX)^{-1}$$

where TX = T - C, T is the temperature argument, and C is a constant. Each function has a lower and upper limit of application. The first function entered must be for the lowest temperature range. The lower limit of each following function must equal the upper bound of the previous function.

W1(R) Lower limit temperature (K, ^oF).

W2(R) Upper limit temperature (K, ^oF).

W3(R) A_0 ($J/m^3 \cdot K$, $Btu/ft^3 \cdot {}^oF$).

W4(R) A_1 ($J/m^3 \cdot K^2$, $Btu/ft^3 \cdot {}^oF^2$).

W5(R) A_2 ($J/m^3 \cdot K^3$, $Btu/ft^3 \cdot {}^oF^3$).

W6(R) A_3 ($J/m^3 \cdot K^4$, $Btu/ft^3 \cdot {}^oF^4$).

W7(R) A_4 ($J/m^3 \cdot K^5$, $Btu/ft^3 \cdot {}^oF^5$).

W8(R) A_5 ($J/m^{3} \cdot$, Btu/ft^3).

W9(R) C (K, ^oF).

11 Cards 202TTTNN, General Table Data

These cards are used only in NEW or RESTART type problems and are required only if any input references general tables. TTT is the table number, and table references such as for power, heat transfer coefficients, and temperatures refer to this number. Data must be entered for each table that is referenced, but TTT need not be consecutive. Tables entered but not referenced are stored, and this is not considered an error. During RESTART, general tables may be added, existing tables may be deleted, or existing tables may be modified by entering new data. Tables for hydrodynamic boundary conditions are not input with these general tables but rather are input with tables in the time dependent volume and time dependent junction hydrodynamic components. Tables associated with pumps are not input with these general tables but rather are input with tables in the pump hydrodynamic component.

11.1 Card 202TTT00, Table Type and Multiplier Data

This card is required.

W1(A) Table type. Enter POWER for power versus time; enter HTC-T for heat transfer coefficient versus time; enter HTRNRATE for heat flux versus time; enter HTC-TEMP for heat transfer coefficient versus temperature; enter TEMP for temperature versus time; enter REAC-T for reactivity versus time; enter NORMAREA for normalized area versus normalized stem position; enter NORMVOL for normalized volume versus normalized stem position or time. In RESTART problems, DELETE can be entered to delete general table TTT. When a general table is used to define a FUNCTION type control system variable, table type REAC-T can be used to prevent undesirable units conversion, since no British to SI units conversion is done for REAC-T entries.

The following two, three, or four words are optional and allow trips and factors or units changes to be applied to the table entries. If the factors are omitted, the data are used as entered. One multiplier is used for time, power, heat flux, heat transfer coefficient, normalized stem position, normalized area, and normalized volume; a multiplier and additive constant are used for temperature as $T = M^2 \cdot TX + C$, where M is the multiplier, C is the additive constant, and TX is the temperature entered. The first one or two factors apply to the argument variable, time or temperature; one factor is applied if the argument is time, and two factors are used if the argument is temperature. The remaining one or two factors are used for the function, two factors being used if temperature is the function.

W2(I) Table trip number. This number is optional unless factors are entered. If missing or zero, no trip is used, and the time argument in the following table is the time supplied to the table for interpolation. If nonzero, the number is the trip number, and the time argument in the following table is -1.0 if the trip is false and the time supplied to the table minus the trip time if the trip is true. This field may be omitted if no factors are entered. This number must be zero or blank for tables that are not a function of time.

W3-W5(R) Factors. As described above, enter factors such that when applied to the table values entered, the resultant values have the appropriate units. For the NORMAREA table, the resultant values for both the normalized length and area must be ≥ 0 and ≤ 1.0.

11.2 Cards 202TTT01 through 202TTT99, General Table Data

The card numbers need not be consecutive. The units given are the units required after the factors on Card 202TTT00 have been applied. Sets of two numbers are entered on each card. Sets may be entered one or more per card and may be split across cards. The total number of words must be a multiple of the set size.

These cards are required.

W1(R) Argument value (s, if time; K, ^oF, if temperature; dimensionless, if normalized stem position).

W2(R) Function value (W, MW, if power; K, ^oF, if temperature; W/m^2, $Btu/s \bullet ft^2$, if heat flux; $W/m^2 \bullet K$, $Btu/s \bullet ft^2 \bullet {}^oF$ if heat transfer coefficient; dollars, if reactivity; dimensionless, if normalized area or normalized volume).

The tables use linear interpolation for segments between table search argument values. For search arguments beyond the range of entered data, the end-point values are used.

12 Cards 30000000 through 30099999, 310000000 through 339999999, 340000000 through 359999999, 390000000 through 399999999, Reactor Kinetics Input

These cards are required if a space-independent (point) reactor kinetics or a nodal reactor kinetics calculation is desired. These cards may be entered in a new problem or on a restart. If no reactor kinetics data are present in a restart problem, the data will be added; if reactor kinetics data are already present, the data are deleted and replaced by the new data. A complete set of reactor kinetics data must always be entered. Initial conditions are computed the same for new or restart problems; the initial conditions can be obtained from assuming infinite operating time at the input power or from an input power history.

12.1 Card 30000000, Reactor Kinetics Type

This card is required for either point or nodal kinetics problems.

W1(A) Kinetics type. Enter POINT, NODAL, or DELETE. Enter POINT for the point reactor kinetics option. Enter NODAL for the nodal reactor kinetics option. Enter DELETE in a restart problem if reactor kinetics is to be deleted. No other data are needed if reactor kinetics is being deleted.

W2(A) Feedback type. Enter SEPARABL, TABLE3, TABLE4, TABLE3A, TABLE4A, RAMONA, HWR, GEN, RBMK, or USER. The first five options are allowed only in POINT kinetics problems, and the last five options are allowed only in NODAL type problems. If Word 2 is not entered, a default value is assumed. If the kinetics type is POINT, the default is SEPARABL. If the kinetics type is NODAL, the default is RAMONA. If SEPARABL is entered, reactor kinetics feedback due to moderator fluid density, void fraction weighted moderator fluid temperature, and volume average fuel temperature is assumed to be separable, and feedback data are entered on Cards 30000501 through 30000899. If TABLE3, TABLE4, TABLE3A, or TABLE4A is entered, reactivity is obtained from a table defining reactivity as a function of three or four variables using Cards 30001001 through 30002999. If TABLE3 or TABLE4 are entered, the variables are moderator fluid density, void fraction weighted moderator fluid temperature, volume average fuel temperature, and boron density. If TABLE3A or TABLE4A is entered, the variables are void fraction, liquid moderator temperature, volume average fuel temperature, and boron concentration. If TABLE3 or TABLE3A is entered, the first three of the variables in one of the sets defined above are used, and if TABLE4 or TABLE4A is entered, all four variables are used. If RAMONA is entered, cross-sections including feedback and control rod effects are computed using a method from the RAMONA code and generalized in the TRAC-BD code. If HWR is entered, the cross-sections including feedback and control rod effects are computed using a formulation specified by the heavy water New Production Reactor project at Savannah River. The GEN cross-section formulation is a more general formulation and the RAMONA and HWR can be manipulated into the GEN form. The RAMONA and HWR input options are retained for backward compatibility and user convenience but the code uses the GEN option internally for simplicity. The RBMK option is used for the graphite moderated, pressure tube type reactors developed by the former Soviet Union. If USER is entered, the neutron cross sections are computed by a user supplied external subroutine.

12.2 Card 30000001, Reactor Kinetics Information

This card is required in both point and nodal kinetics problems, but the format is slightly different between the two problem types in that Words 3 and 4 input different quantities.

12.2.1 Point Kinetics Format

W1(A) Fission product decay type. Enter NO-GAMMA for no fission product decay calculations, GAMMA for standard fission product decay calculations, or GAMMA-AC for fission product decay plus actinide decay calculations.

W2(R) Total reactor power (W). This is the sum of immediate (prompt and delayed neutrons) fission power, fission product decay power, and actinide decay power. Watts are used for both SI and British units. This quantity must be greater than 0.0.

W3(R) Initial reactivity (dollars). This quantity must be less than or equal to 0.0. It is recommended that this quantity be less than or equal to $-1.0e^{-60}$; otherwise, the CPU time may increase dramatically.

W4(R) Delayed neutron fraction divided by prompt neutron generation time, $\frac{\beta}{\Lambda}$ (s^{-1}). This quantity must be greater than 0.0.

W5(R) Fission product yield factor. This is usually 1.0 for best-estimate problems, and 1.2 has been used with ANS73 data for conservative mode problems. The factor 1.0 is assumed if this word is not entered.

W6(R) ^{239}U yield factor. This is the number of ^{239}U atoms produced per fission times any conservative factor desired. The factor 1.0 is assumed if this word is not entered.

W7(R) Fissions per initial fissile atom, ψ_g. Used in factor $G(t) = 1.0 + (3.24 \cdot 10^{-6} + 5.23 \cdot 10^{-10}t)$ $T^{0.4}\psi_g$ to account for neutron capture in fission products when using the ANS79-1, ANS79-3, ANS94-1, or ANS94-4 option. This word is not allowed with the ANS73 option. Entering this quantity as a nonzero includes the G factor as part of the decay heat.

The factor is not included if this quantity is not entered or is entered as zero. Entering this word as a positive quantity indicates that the equation is to be used for shutdown time up to 10^4 s, and the table is to be used from that time on. Entering this word as a negative number indicates that the table is to be used for all shutdown times. Note that there is a discontinuity in G(t) when switching between the equation and the table. The standard indicates that the table can be used for all shutdown times and that would result in a higher neutron absorption capture effect. The magnitude of this quantity if nonzero must be greater than or equal to 1.0 and less than or equal to 3.0.

W8(R) Reactor operating time T. This quantity is the T in the expression given in W7 above. This word is not allowed with the ANS73 option. The unit for this quantity is given in the next word. If not entered or entered as zero, this quantity defaults to 52 wk. This quantity is used only if the power history data in Section 12.15 are not entered. When the power history data are entered, the reactor operating time is obtained from that data. When the power history data are not entered, an infinite operating time is assumed in initializing the decay heat variables, and if the equation form of G(t) is being used, the quantity in this word is used with the shutdown period t set to zero to determine the G factor at the start of the simulation. This quantity must be less than or equal to $1.2614 \cdot 10^8$ seconds.

W9(A) Units for W8 above. Must be SEC, MIN, HR, DAY, or WK. This word is not allowed with the ANS73 option.

12.2.2 Nodal Kinetics Format

W1(A) Fission product decay type. Enter NO-GAMMA for no fission product decay calculations, GAMMA for standard fission product decay calculations, or GAMMA-AC for fission product decay plus actinide decay calculations.

W2(R) Total reactor power (W). This is the sum of immediate (prompt and delayed neutrons) fission power, fission product decay power, and actinide decay power. Watts are used for both SI and British units.

W3(R) Delayed neutron fraction β. This number must be greater than 0.0 and less than 0.1.

W4(I) Number of delayed neutron groups. Must be greater than 0 and less than 50.

W5(R) Fission product yield factor. This is usually 1.0 for best-estimate problems, and 1.2 has been used with ANS73 data for conservative mode problems. The factor 1.0 is assumed if this word is not entered.

W6(R) ^{239}U yield factor. This is the number of ^{239}U atoms produced per fission times any conservative factor desired. The factor 1.0 is assumed if this word is not entered.

W7(R) Fissions per initial fissile atom, ψ_g. Used in factor G(t) = 1.0 + (3.24x10^{-6} + 5.23x10^{-10}t) $T^{0.4}\psi_g$ to account for neutron capture in fission products when using ANS79-1, ANS79-3, ANS94-1, or ANS94-4 option. This word is not allowed with the ANS73 option. Entering this quantity as a nonzero includes the G factor as part of the decay heat. The factor is not included if this quantity is not entered or is entered as zero. Entering this word as a positive quantity indicates that the equation is to be used for shutdown time up to 10^4 s, and the table is to be used from that time on. Entering this word as a negative number indicates that the table is to be used for all shutdown times. Note that there is a discontinuity in G(t) when switching between the equation and the table. The standard indicates that the table can be used for all shutdown times and that would result in a higher neutron absorption capture effect. The magnitude of this quantity if nonzero must be greater than or equal to 1.0 and less than or equal to 3.0.

W8(R) Reactor operating time T. This quantity is the T in the expression given in W7 above. This word is not allowed with the ANS73 option. The unit for this quantity is given in the next word. If not entered or entered as zero, this quantity defaults to 52 wk. This quantity is used only if the power history data in Section 12.15 are not entered. When the power history data are entered, the reactor operating time is obtained from that data. When the power history data are not entered, an infinite operating time is assumed in initializing the decay heat variables, and if the equation form of G(t) is being used, the quantity in this word is used with the shutdown period t set to zero to determine the G factor at the start of the simulation. This quantity must be less than or equal to $1.2614 \bullet 10^8$ s.

W9(A) Units for W8 above. Must be SEC, MIN, HR, DAY, or WK. This word is not allowed with the ANS73 option.

12.3 Card 30000002, Fission Product Decay Information

This card is optional for POINT or NODAL problems if W1 of Card 30000001 contains GAMMA or GAMMA-AC. If this card is not entered, an approximation to the Proposed 1973 ANS Standard fission product data are used if default data are used. Two, five, six, eight, or ten data items may be entered on this card depending on the value of Word 1 on this card. Two data items may be entered for fission product types ANS73 , ANS79-1, or ANS94-1; five or eight data items may be entered for fission product type ANS79-3; and six or ten data items may be entered for fission product type ANS94-4. If only five data items are entered for fission product type ANS79-3, the default number of decay heat groups (i.e., 23) is used for each of the three fissionable isotopes. If only six data items are entered for fission type ANS94-4, the default number of decay heat groups (i.e., 23) is used for each of the four fissionable isotopes.

W1(A) Fission product type. Enter ANS73, ANS79-1, ANS79-3, ANS94-1, or ANS94-4. If default fission product data are used, ANS73 specifies an approximation to the Proposed 1973 ANS Standard data; ANS79-1 specifies the 1979 Standard data for ^{235}U; ANS79-3 specifies the 1979 ANS Standard data for the three isotopes, ^{235}U, ^{238}U, and ^{239}Pu; ANS94-1 specifies the 1994 ANS Standard data for ^{235}U; and ANS94-4 specifies the 1994 ANS Standard data for the four isotopes ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu. ANS79-3 and ANS94-4 also require that power fractions for each isotope be entered. If fission product data are entered, ANS73, ANS79-1, and ANS94-1 specify only one isotope and ANS79-3 and ANS94-4 specify three and four isotopes, respectively, and also require that the number of decay heat groups for each isotope be entered.

W2(R) Energy release per fission (MeV/fission). If not entered or zero, the default value of 200 MeV/fission is used.

The following data are required if ANS79-3 is entered as Word 1 on this card and should not be entered for the other decay heat options.

W3-W5(R) If ANS79-3 is specified in W1, the fraction of the power generated by fission of ^{235}U, ^{238}U, and ^{239}Pu must be entered in these three words. The sum of the fractions must add to one.

The following data items are optional if ANS79-3 is entered as Word 1 on this card and should not be entered for the other decay heat options.

W6-W8(I) Number of decay heat groups per isotope. If ANS79-3 is entered in W1 and default data are not being used, the number of decay groups for ^{235}U, ^{238}U, and ^{239}Pu must be entered in these words. The number of groups for each isotope must be less than or equal to 50.

The following data are required if ANS94-4 is entered as Word 1 on this card and should not be entered for the other decay heat options.

W3-W6(R) If ANS94-4 is specified in Word 1, the fraction of the power generated by fission of ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu must be entered in these four words. The sum of the fractions must add up to one.

The following data items are optional if ANS94-4 is entered as Word 1 on this card and should not be entered for the other decay heat options.

W7-W10(I) Number of decay heat groups per isotope. If ANS94-4 is entered in Word 1 and default data are not being used, the number of decay groups for ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu must be entered in these words. The number of groups for each isotope must be less than of equal to 50.

12.4 Card 30000003, Nodal Kinetics Control Information

This card is required for NODAL type problems.

W1(I) Number of nodal axial mesh intervals (in the z direction). This quantity must be greater than 0 and less than 100. The default value is 1.

W2(I) Number of nodal mesh intervals in the x direction on each mesh plane. This quantity must be greater than 0 and less than or equal to 100. If the following word is 0, this word is the number of rings of meshes surrounding the central mesh for hexagonal geometry.

W3(I) Number of nodal mesh intervals in the y direction on each mesh plane. A value of 0 indicates hexagonal geometry. This quantity must be greater than or equal to 0 and less than or equal to 100.

W4(I) Number of neutron groups. Only values of 2 and 4 are allowed and the default value is 2. This value must be 2 for the RBMK neutron cross section option.

W5(I) Number of thermal neutron groups. The default value is 1.

W6(I) Mesh symmetry flag. A value of 1 indicates that a full core is being simulated (this can be used for either Cartesian geometry or hexagonal geometry). Values of 2 or 4 indicate half and quarter symmetry for Cartesian geometry while values of 3 or 6 indicate third core or sixth core symmetry in hexagonal geometry. The default value is 1.

W7(I) Mesh plane exterior boundary condition flag. A value of 0 indicates a zero current boundary condition, a value of 1 indicates a zero flux boundary condition, a value of 2 indicates a non-reentrant current boundary condition, and a value of 3 indicates a cyclic rotational) boundary condition. The default value is 1.

W8(I) Mesh plane interior boundary condition flag. The values are the same as the exterior boundary condition flag. The default value is 0.

W9(I) Top axial boundary condition flag. The values are the same as the exterior boundary condition flag. The default value is 0.

W10(I) Bottom axial boundary condition flag. The values are the same as the exterior boundary condition flag. The default value is 0.

W11(I) Maximum number of thermal scattering iterations. The value must be be greater than or equal to one and less than or equal to 100. Default value is 100.

W12(I) Maximum number of outer iterations per invocation of either the steady-state LSOR or transient LSOR solution modules. The value must be greater than or equal to one and less than or equal to 500. Default value is 500.

W13(I) Number of outer iterations between computation of nodal expansion method coupling coefficients for the LSOR solver. A value of 0 indicates that the coarse mesh diffusion method is to be used while a value greater than 0 indicates that the nodal expansion solution techniques is to be used. This value must be greater than or equal to zero and less than or equal to 50. If the order of the Chebyshev fission source extrapolation polynomial specified in the next word (Word 14) is greater than zero and this value is greater than zero, this value must be greater than the order of the Chebyshev fission source extrapoation polynomial (i.e.,Word 14). Default value is 0.

W14(I) Maximum order of Chebyshev fission source extrapolation polynomial for the LSOR solver. A value of 0 indicates that Chebyshev fission source extrapolation not be used while a value greater than 0 indicates that Chebyshev acceleration is to be used. If Chebyshev fission source extrapolation is used, the order of the polynomial must be greater than or equal to three and less than or equal to 20 (i.e., the minimum polynomial order is 3). Default value is 0.

W15(I) Number of outer iterations per transient time step for the LSOR solver. A value of 0 indicates that the convergence criteria are used to terminate the outer iterations each transient time step while a value greater than 0 indicates that a fixed number of outer iterations are to be used. This value must be greater than or equal to zero and less than or equal to 50. Default value is 0. The recommended option is to use the convergence criteria to terminate the outer iterations each time step and the use of a fixed number of iterations is strongly discouraged.

W16(I) Print control flag. A value of 0 indicates no printed output from the kinetics modules, a value of 1 indicates only convergence information is to be written to the printed output at each iteration in the kinetics solution and a value of 2 indicates convergence information, neutron cross-sections, fluxes, powers, power densities, and power distributions are to be written on the printed output at the end of each call to the kinetics modules. Values other than zero should be used with care since they produce voluminous output, can easily make extremely large output files, and should only be used for debugging purposes.

W17(I) Transient solution algorithm flag. A value of 0 indicates that the LSOR (line successive over-relaxation) solution algorithm is to be used in transient mode. A value of 1 indicates that the Krylov solution algorithm is to be used in transient mode. The default value is 0.

W18(R) Value used in the figures for the multi-dimensional neutron kinetics model to specify that the node is not part of the kinetics solution domain. This number is used for error checking purposes, and must not be the same as any valid figure entry. The figures that use this value are the figures containing decimal numbers as opposed to the figures whose entries are integers. These figures are the initial power distribution figures (Cards 3005ZZ01 - 3005ZZ99), User Variable 1 figures (Cards 3006UU01 - 3006UU99), User Variable 2 figures (Cards 3007UU01 - 3007UU99), User Variable 3 figures (Cards 3008UU01 - 3008UU99), User Variable 4 figures (Cards 3009UU01 - 3009UU99), and Bundle Rotation figures (Cards 3010RR01 - 3010RR99). The default value is -1.0.

12.5 Card 30000004, Nodal Kinetics Control Parameters

This card is optional for NODAL type problems.

W1(R) Eigenvalue convergence criterion for the LSOR solver. Default value is 1.0×10^{-6}.

W2(R) Outer iteration L infinity norm convergence criterion for the LSOR solver. Default value is 1.0×10^{-6}.

W3(R) Outer iteration L2 norm convergence criterion for the LSOR solver. Default value is 1.0×10^{-5}.

W4(R) Inner iteration L2 norm convergence criterion for the LSOR solver. Default value is 1.0×10^{-3}.

W5(R) Outer iteration L2 relative error reduction criteria for NEM coupling coefficient update for the LSOR solver. Default value is 1.0×10^{-2}.

12.6 Card 30000005, Neutron Velocity Data

This card is required for NODAL type problems. Note that the units are cm/s rather than m/s.

W1(R) Group 1 neutron velocity (cm/s).

W2(R) Group 2 neutron velocity (cm/s).

W3(R) Group 3 neutron velocity (cm/s).

W4(R) Group 4 neutron velocity (cm/s).

12.7 Card 30000006, Prompt Neutron Fission Spectrum Data

This card is required for NODAL type problems. The values must sum to 1.

W1(R) Group 1 prompt neutron fission yield.

W2(R) Group 2 prompt neutron fission yield.

W3(R) Group 3 prompt neutron fission yield.

W4(R) Group 4 prompt neutron fission yield.

12.8 Card 30000007, Delayed Neutron Fission Spectrum Data

This card is optional for NODAL type problems. The values are the fission yields for the delayed neutron precursors by neutron energy group for each of the precursors. The values must sum to 1 for each delayed neutron precursor groups.

W1(R) Group 1 delayed neutron precursor yield for delayed group 1.

W2(R) Group 2 delayed neutron precursor yield for delayed group 1.

W3(R) Group 1 delayed neutron precursor yield for delayed group 2.

W4(R) Group 2 delayed neutron precursor yield for delayed group 2.

12.9 Card 30000008, Xenon/Samarium Calculation Option

This card is optional for NODAL type problems. The first word is an integer flag that determines what type of Xenon/Samarium concentration calculation is performed. If this quantity is 0, no Xenon/Samarium calculation is performed. If this quantity is 1, equilibrium Xenon and Samarium are calculated in steady-state and frozen at that value for the transient. If this quantity is 2, equilibrium Xenon and Samarium are calculated in steady-state and permitted to vary during the transient. If this quantity is 3, equilibrium Xenon is calculated in steady-state and frozen at that value for the transient (no Samarium concentrations are calculated). If this quantity is 4, equilibrium Xenon is calculated in steady-state and permitted to vary during the transient (no Samarium concentrations are calculated). The second word is an integer flag that determines if the fast time option for the Xenon/Samarium calculations is invoked. If this quantity is 0, no fast time option is invoked. If this quantity is greater than 0 and less than 1000, then it refers to the general table number that contains the multiplier to use for the fast time option. If this quantity is greater than 10000, then it refers to a control variable (value-10000) that provides the multiplier for the fast time option. W4 contains the fast time option for the decay heat computation.

W1(I) Xenon/Samarium calculation option. The default value is 0.

W2(I) Fast time calculation option for Xenon/Samarium. The default value is 0.

W3(R) Xenon/Samarium steady-state convergence adjustment parameter. The default value is 1.0.

W4(I) Fast time calculation option for decay heat. The default value is 0.

12.10 Card 30000009, Core Age Parameter

This card is optional for NODAL type problems. The value represents the burnup state of the core. Typical values are 0 for beginning of cycle (BOC), 1 for middle of cycle (MOC), and 2 for end of cycle (EOC).

W1(I) Core age parameter. Default value is 1.

12.11 Card 30000010, Krylov Solution Algorithm Information

This card is optional for NODAL type problems. It contains control information for the Krylov transient solution algorithm.

W1(I) Neutron precursor solution type. A value of 0 selects an explicit solution and a value of 1 selects an implicit solution. The default value is 1.

W2(I) Matrix preconditioner frequency. The variable is the maximum number of time steps between the computation of the Krylov matrix preconditioner. The default value is 0 (compute matrix preconditioner every time step).

W3(I) Maximum number of outer iterations per time step for the transient Krylov solver. A value of 0 means iterate to convergence. A value greater than 0 indicates to take a fixed number of outer iterations each time step. The default value is the value in W15 of Card 30000003.

W4(I) Number of intervals between nodal coupling coefficient computations for the transient Krylov solver. A value of 0 means no nodal coupling computation. The number of intervals specified by this word is interpreted as the number of iterations between the computation of the nodal coupling coefficients if the maximum number of outer iterations per time step specified in the previous word (Word 3) on this card is zero (i.e., terminate the outer iterations based on the convergence criteria). If the value of the previous word (Word 3) is greater than zero (i.e., terminate the outer iterations after a fixed number of iterations), the number of intervals between the computation of the nodal coupling coefficients is interpreted as the number of time steps between the computation of the nodal coupling coefficients rather than the number of iterations between the computation of the nodal coupling coefficients. The default value is the value of Word 13 of Card 30000003.

W5(R) Theta value to neutron flux solution. Value must be greater than or equal to 0.5 and less than or equal to 1.0. A value of 1.0 means a fully implicit solution and a value of 0.5 indicates a Crank-Nicholson solution. The default value is 1.0.

W6(R) Outer iteration L2 norm convergence criteria for the transient Krylov solver. The default value is the value in W3 on Card 30000004.

W7(R) Outer iteration R2 norm convergence criteria for the transient Krylov solver. The default value is 1.0×10^{-3}.

W8(R) Outer iteration L infinity norm convergence criteria for the transient Krylov solver. The default value is the value of W2 on Card 30000004.

W9(R) NEM update convergence criteria for the transient Krylov solver. The default value is the value in W5 of Card 30000004.

12.12 Cards 30000101 through 30000199, Delayed Neutron Constants

If these cards are missing, constants for the six generally accepted delayed neutron groups (N_d) are supplied. Otherwise, two numbers for each delay group are entered, one or more pairs per card. Card numbers need not be consecutive. The number of pairs on these cards defines the number of delayed neutron precursor groups. Up to 50 delayed neutron precursor groups (N_d) may be entered. The delayed neutron precursor yield ratios must sum to one within a relative error of 1.0×10^{-6}.

W1(R) Delayed neutron precursor yield ratio, f_i (= β_i/β).

W2(R) Delayed neutron decay constant, λ_i (s^{-1}).

12.13 Cards 30000201 through 30000299, Fission Product Decay Constants

These cards are not needed if W1 of Card 30000001 is NO-GAMMA. If this word is GAMMA or GAMMA-AC, data from these cards or default data are used to define fission product decay. If the cards are missing, data as defined in W1 of Card 30000002 are supplied. Up to 50 fission product groups may be entered. Data are entered on cards similarly to Cards 30000101 through 30000199. The factor in W5 of Card 30000001 is applied to the yield fractions.

W1(R) Fission product yield fraction.

W2(R) Fission product decay constant (s^{-1}).

12.14 Cards 30000301 through 30000399, Actinide Decay Constants

These cards are not needed unless W1 of Card 30000001 is GAMMA-AC. If GAMMA-AC is entered, data from these cards or default data are used to define actinide decay. If the cards are missing, default data are supplied.

W1(R) Energy yield from ^{239}U decay (Mev).

W2(R) Decay constant of ^{239}U (s^{-1}).

W3(R) Energy yield from ^{239}Np (Mev).

W4(R) Decay constant of ^{239}Np (s^{-1}).

12.15 Cards 30000401 through 30000499, Power History Data

If these cards are not present, initial conditions for fission product and actinide groups are for steady-state operation at the power given in W2 of Card 30000001. This is equivalent to operation at that power for an infinite time. If these cards are present, the power history consisting of power and time duration is used to determine the fission product and actinide initial conditions. The power from gamma and actinide decay is assumed to be zero at the beginning of the first time duration. Data are entered in three-word, six-word, or seven-word sets, one or more sets per card. Card numbers need not be consecutive.

W1(R) Reactor power (W). This quantity is the total reactor power, that is, the sum of fission power and decay power, and must be ≥ 0. If a decay power obtained from the power history exceeds this quantity, the fission power is assumed to be 0.

W2(R) Time duration. Units are as given in next word. This quantity must be ≥ 0.

W3(A) Time duration units. Must be SEC, MIN, HR, DAY, or WK.

The following data are required if ANS79-3 is entered as Word 1 on Card 30000002 and should not be entered for the other decay heat options.

W4-W6(R) Power fractions. The power fractions for ^{235}U, ^{238}U, and ^{239}Pu must be entered in these words.

The following data are required if ANS94-4 is entered as Word 1 on Card 30000002 and should not be entered for the other decay heat options.

W4-W7(R) Power fractions. The power fractions for ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu must be entered in these words.

12.16 Point Kinetics Feedback Input

Feedback information for point kinetics information are entered on the following cards. For steady-state computations in which constant power is desired, these cards can be omitted and the feedback reactivity will be zero.

12.16.1 Cards 30000011 through 30000020, Reactivity (or Scram) Curve or Control Variable Numbers

Reactivity (or scram) curves from the general tables (Cards 202TTTNN) or control variables that contribute to reactivity feedback are specified on these cards. These cards are not used if there are no references to reactivity contributions from general tables or control variables. Tables and control variables referenced must be defined. No error is indicated if reactivity curves are defined but not referenced on this card, but memory space is wasted. Curve numbers, which are the TTT of the general table card number or control variable number code, are entered one or more per card. Card numbers need not be consecutive.

W1(I) Table or control variable number. Up to 20 numbers may be entered. Numbers from 1 through 999 indicate general table numbers. Numbers greater than 10000 indicate the control variable whose number is the entered number minus 10000.

12.16.2 Cards 30000501 through 30000599, Density Reactivity Table

This table is required if the SEPARABL option is being used and if Cards 30000701 through 30000799 are entered. One or more pairs of numbers are entered to define reactivity as a function of moderator density. The densities must be non-negative and must be entered in increasing magnitude. Data are entered one or more pairs per card, and card numbers need not be consecutive. Up to 100 pairs may be entered. The table uses linear interpolation for segments between table search argument values. For search arguments beyond the range of entered data, the end-point values are used.

W1(R) Moderator density (kg/m^3, lb_m/ft^3), ρ.

W2(R) Reactivity (dollars), R_ρ. See Volume I of this manual for a discussion of the symbols.

12.16.3 Cards 30000601 through 30000699, Doppler Reactivity Table

This table is required if the SEPARABL option is being used and if Cards 30000801 through 30000899 are entered. One or more pairs of numbers are entered to define Doppler reactivity as a function of heat structure volume average fuel temperature. The temperatures must be positive and must be entered in increasing magnitude. Heat structure composition data Cards 1CCCG201 through 1CCCG209 need to exclude the gap and the cladding for the heat structure volume average fuel temperatures. Data are entered one or more pairs per card, and card numbers need not be consecutive. Up to 100 pairs may be entered. The table uses linear interpolation for segments between table search argument values. For search arguments beyond the range of entered data, the end-point values are used.

W1(R) Fuel temperature (K, ^oF), T_F.

W2(R) Reactivity (dollars), R_F. See Volume I of this manual for a discussion of the symbols.

12.16.4 Cards 30000701 through 30000799, Volume Weighting Factors and Coefficients

These cards are used only if the SEPARABL option is being used and are omitted if no reactor kinetics feedback from hydrodynamics is present. Each card contains the input for reactivity feedback due to conditions in one or more hydrodynamic volumes. Words 1 and 2 are a volume number and an increment. Words 3 and 4 are the reactivity data for the volume defined by Word 1; Words 5 and 6 are the reactivity data for the volume defined by Word 1 plus Word 2; Words 7 and 8 are the reactivity data for the volume defined by Word 1 plus two times Word 2; etc. Each card must contain at least four words. Volumes referenced by these cards must be defined by hydrodynamic component data cards, and any volume reactivity data must be defined only once on these cards. Card numbers need not be consecutive.

Usually, Word 4 is zero. If the reactivity is linear in density, one should use the table (with weighting factors) or the coefficients, but not both. If the reactivity is nonlinear in density, the table (with weighting factors) should be used. If the coefficients (i.e., Word 4) are non-zero, the reactivity coefficients derived from the density table should be zero.

W1(I) Hydrodynamic volume number.

W2(I) Increment.

W3(R) Weighting factor for density feedback, $W_{\rho i}$. See Volume I of this manual for a discussion of the symbols. This word must be greater than zero.

W4(R) Liquid temperature coefficient, a_{Wi} (dollars/K, dollars/^{o}F). As defined in Volume I, the weighting factor in Word 3 is not applied to this quantity.

12.16.5 Cards 30000801 through 30000899, Heat Structure Weighting Factors and Coefficients

These cards are used only if the SEPARABL option is being used and are omitted if no reactor kinetics feedback from heat structures are present. Each card contains the input for reactivity feedback due to conditions in one or more heat structures representing fueled portions of the reactor. Words 1 and 2 are a heat structure number and an increment. Words 3 and 4 are the reactivity data for the heat structure defined by Word 1; Words 5 and 6 are the reactivity data for the heat structure defined by Word 1 plus Word 2; Words 7 and 8 are the reactivity data for the heat structure defined by Word 1 plus two times Word 2; etc. Each card must contain at least four words. Heat structures referenced by these cards must be defined by heat structure component data cards, and any heat structure reactivity data must be defined only once on these cards. Card numbers need not be consecutive.

For each heat structure specified on these cards, input on the heat structure data Cards 1CCCG2NN must define the fueled region as the region over which the volume-average temperature is computed.

Usually, Word 4 is zero. If the reactivity is linear in fuel temperature, one should use the table (with weighting factors) or the coefficients, but not both. If the reactivity is nonlinear in fuel temperature, the table (with weighting factors) should be used. If the coefficients (i.e., Word 4) are non-zero, the reactiviety coefficients derived from the DOppler table should be zero.

W1(I) ATHENA heat structure number.

W2(I) Increment.

W3(R) Weighting factor for Doppler feedback, W_{Fi}. See Volume I of this manual for a discussion of the symbols. This word must be greater thatn zero.

W4(R) Fuel temperature coefficient, a_{Fi} (dollars/K, dollars/^{o}F). As defined in Volume I, the weighting factor in Word 3 is not applied to this quantity.

12.16.6 Cards 30001701 through 30001799, Volume-Weighting Factors

These cards are used only if the TABLE3, TABLE3A, TABLE4, or TABLE4A option is not being used. Each card contains the weighting factor for reactivity feedback due to moderator fluid density (void fraction), void weighted moderator fluid temperature (liquid moderator temperature), and spatial boron density (boron concentration) in one or more hydrodynamic volumes. The quantities preceding the quantities within parentheses are used if TABLE3 or TABLE4 has been entered; the quantities within parentheses are used if TABLE3A or TABLE4A has been entered. The same factor is assumed to apply to all three effects, so only one factor is entered for each value. At least three quantities must be entered on each card. The use of the increment field is similar to that in Section 12.16.4.

W1(I) Hydrodynamic volume number.

W2(I) Increment.

W3(R) Weight factor, $W_{\rho i}$.

12.16.7 Cards 30001801 through 30001899, Heat Structure Weighting Factors

These cards are used only if the TABLE3, TABLE 3A, TABLE4, or TABLE4A option is being used. Each card contains the weighting factor for reactivity feedback due to heat structure volume average fuel temperature in one or more heat structures. At least three quantities must be entered on each card. The use of the increment field is similar to that in Section 12.16.4.

W1(I) ATHENA heat structure number.

W2(I) Increment.

W3(R) Weight factor, W_{Fi}.

12.16.8 Cards 300019C1 through 300019C9, Feedback Table Coordinate Data

If the TABLE3 or TABLE3A option is being used, the feedback table is a function of three variables: moderator fluid density or void fraction (C = 1), void fraction weighted moderator fluid temperature or liquid moderator temperature (C = 2), and heat structure volume average fuel temperature (C = 3). If the TABLE4 or TABLE4A option is being used, the feedback table is a function of four variables: the three above and spatial boron density or boron concentration (C = 4). Which variables are used depend on the feedback option used (see W2, Card 30000000 in Section 12.1). These cards define the coordinates of the table, and table values are entered (on another card set) for each point defined by all combinations of the coordinate values. The table size is the product of the number of coordinate values entered for each variable. At least two coordinate points must be entered, and up to twenty points may be entered for each variable. The table uses multi-dimensional interpolation for values between table coordinate values. For values beyond the range of the entered coordinate values, the end-point coordinate values are used. Coordinate values must be entered in increasing magnitude, one or more per card on one or more cards as desired. Card numbers need not be consecutive. The C in the parentheses above defines the C to be used in the card number.

W1(R) Coordinate value [kg/m^3, lb_m/ft^3 for moderator and spatial boron densities; K, ^oF for moderator and heat structure temperatures; void fractions and boron concentrations (mass of boron per mass of liquid) are dimensionless].

12.16.9 Cards 30002001 through 30002999, Feedback Table Data

Values defining the table are entered in pairs. The first is a coded number defining the position of the table entry. The second number is the table entry. One or more pairs may be entered on one or more cards as needed. Card numbers need not be consecutive. There is no required ordering for the coded number, but a coded number may be entered only once.

W1(I) Coded number. The coded number has the form ddmmffbb, where the letter pairs represent coordinate numbers of the independent variables of the table. The dd pair refers to moderator fluid density or void fraction, mm refers to void weighted moderator fluid temperature or liquid moderator temperature, ff refers to heat structure volume average heat structure temperature, and bb refers to spatial boron density or boron concentration. The paired numbers range from 00 to one less than the number of coordinate values for that variable. The 00 pair refers to the first coordinate value. If boron dependence is not included, bb is always 00. All table values must be entered. (A future version may allow gaps that are filled in by interpolation.)

W2(R) Table value.

12.17 Nodal Kinetics Feedback Input

The description of the nodal kinetics mesh assumes a reactor core divided into axial slices with the stack of mesh planes starting at the bottom of the core and extending upward. This assumption is for descriptive purposes only and no orientation is built into input processing.

12.17.1 Cards 30010101 through 30010199, Bottom-Top (Z) Mesh Intervals

Axial mesh intervals (axial plane heights) starting from the bottom and extending to the top of the core are entered in sequential expansion format on these cards. The number of intervals after expansion must equal W1 of Card 30000003. The sequential expansion input consists of pairs of numbers with the last mesh interval number equalling W1 of Card 30000003. Pairs of words are entered as needed.

W1(R) Mesh interval (m, ft).

W2(I) Kinetics mesh interval number.

12.17.2 Cards 30010201 through 30010299, West-East (X) Mesh Intervals or Hexagonal Mesh Size

For Cartesian geometry, enter mesh intervals (node size in the x direction) starting from the left side of the axial slice as viewed from the top of the reactor core and extending to the right side of the axial slice are entered in sequential expansion format on these cards. The number of intervals after expansion must equal W2 of Card 30000003. The sequential expansion input consists of pairs of numbers with the last mesh interval number equalling W2 of Card 30000003. Pairs of words are entered as needed. For hexagonal geometry, a single pair of numbers is entered because all meshes (nodes) in hexagonal geometry are assumed to be the same size. The kinetics mesh interval number entered must have a value of one. The first word on this card is the distance between opposite faces of the hexagonal node (see Figure 7.2-1 of Vol I).

W1(R) Mesh interval (m, ft).

W2(I) Kinetics mesh interval number.

12.17.3 Cards 30010301 through 30010399, North-South (Y) Mesh Intervals

For Cartesian geometry, mesh intervals (node size in the y direction) starting from the top of the axial slice as viewed from the top of the reactor and extending down to the bottom of the axial slice are entered in sequential expansion format on these cards. The number of intervals after expansion must equal W3 of Card 30000003. The sequential expansion input consists of pairs of numbers with the last mesh interval number equalling W3 of Card 30000003. Pairs of words are entered as needed. This card is not used for hexagonal geometry and must not be entered.

W1(R) Mesh interval (m, ft).

W2(I) Kinetics axial mesh interval number.

12.17.4 Cards 30010401 through 30010499, Assignment of Zone Figures to Axial Mesh Intervals

Mesh intervals for the nodal kinetics calculation (node height) are usually smaller than for the hydrodynamic mesh (hydrodynamic volumes) in the axial direction. Zone figures are the first step used to relate the kinetics nodes to the hydrodynamic volumes and heat structures. A figure is a diagram of the layout of the kinetics nodes on a mesh plane when viewing the mesh plane from the top of the kinetics mesh. This input assigns zone figures to axial mesh intervals (x-y planes) starting from the bottom and extending to the top of the kinetics mesh using sequential expansion format. The next set of input assigns composition figures to axial mesh intervals (x-y planes) starting from the bottom and extending to the top of the kinetics mesh using sequential expansion format. The input then assigns zone identifiers to each kinetics node in the (x-y plane) zone figures, composition identifiers to each kinetics node in the (x-y plane) composition figures, and control rod identifiers for each kinetics node (same for each x-y plane). Each zone must contain only contiguous kinetics mesh intervals. Each zone must have a unique zone number, but the zone numbers need not be sequential or even be in increasing order. Pairs of words are entered as needed with the last mesh interval number equaling Word 1 of Card 30000003.

W1(I) Zone figure number. A zone figure number must be greater than 0 and less than 100.

W2(I) Kinetics axial mesh interval number.

12.17.5 Cards 30010501 through 30010599, Assignment of Composition Figures to Axial Mesh Intervals

Composition figures are assigned to kinetics axial mesh intervals (x-y planes) starting from the bottom and extending to the top of the core using sequential expansion format. There are no restrictions on the assignment of composition figures to mesh intervals and intervals in the same zone may have different compositions.

W1(I) Composition figure number. A composition figure number must be greater than 0 and less than 100.

W2(I) Kinetics axial mesh interval number.

....

12.17.6 Cards 30010600, User Variable 1 Axial Distribution

This card is optional and may only be used if the USER feedback option has been specified as W2 on Card 30000000. The axial distribution of user variable 1 is specified in sequential expansion format as pairs of values, the first number representing a weighting factor and the second number representing the axial levels to which the weighting factor should be applied. If this card is input, only one figure of the values of user variable 1 is allowed in the input deck.

W1(R) Weighting factor.

W2(I) Kinetics axial mesh interval number.

....

12.17.7 Cards 30010601 through 30010699, Assignment of User Variable 1 Figures to Axial Mesh Intervals

These cards are optional and may only be entered if the RBMK or USER feedback options have been specified as W2 on Card 30000000. These cards may not be entered if Card 30010600 is entered and vice-versa. Figures of user variable 1 are assigned to axial mesh intervals (x-y planes) starting from the bottom and extending to the top of the core using sequential expansion format. There are no restrictions on the assignment of figures of user variable 1 to mesh intervals.

W1(I) User variable 1 figure number. A user variable 1 figure number must be greater than zero and less than 100.

W2(I) Kinetics axial mesh interval number.

....

12.17.8 Cards 30010700, User Variable 2 Axial Distribution

This card is optional and may only be used if the RBMK or USER feedback options have been specified as W2 on Card 30000000. The axial distribution of user variable 2 is specified in sequential expansion format as pairs of values, the first number representing a weighting factor and the second number representing the axial levels to which the weighting factor should be applied. If this card is input, only one figure of the values of user variable 2 is allowed in the input deck.

W1(R) Weighting factor.

W2(I) Kinetics axial mesh interval number.

....

12.17.9 Cards 30010701 through 30010799, Assignment of User Variable 2 Figures to Axial Mesh Intervals

These cards are optional and may only be entered if the RBMK or USER feedback options have been specified as W2 on Card 30000000. These cards may not be entered if Card 30010700 is entered and vice-versa. Figures of user variable 2 are assigned to axial mesh intervals (x-y planes) starting from the bottom and extending to the top of the core using sequential expansion format. There are no restrictions on the assignment of figures of user variable 2 to mesh intervals.

W1(I) User variable 2 figure number. A user variable 2 figure number must be greater than zero and less than 100.

W2(I) Kinetics axial mesh interval number.

....

12.17.10 Cards 30010800, User Variable 3 Axial Distribution

This card is optional and may only be used if the RBMK or USER feedback options have been specified as W2 on Card 30000000. The axial distribution of user variable 3 is specified in sequential expansion format as pairs of values, the first number representing a weighting factor and the second number representing the axial levels to which the weighting factor should be applied. If this card is input, only one figure of the values of user variable 3 is allowed in the input deck.

W1(R) Weighting factor.

W2(I) Kinetics axial mesh interval number.

....

12.17.11 Cards 30010801 through 30010899, Assignment of User Variable 3 Figures to Axial Mesh Intervals

These cards are optional and may only be entered if the RBMK or USER feedback options have been specified as W2 on Card 30000000. These cards may not be entered if Card 30010800 is entered and vice-versa. Figures of user variable 3 are assigned to axial mesh intervals (x-y planes) starting from the bottom and extending to the top of the core using sequential expansion format. There are no restrictions on the assignment of figures of user variable 3 to mesh intervals.

W1(I) User variable 3 figure number. A user variable 3 figure number must be greater than zero and less than 100.

W2(I) Kinetics axial mesh interval number.

....

12.17.12 Cards 30010900, User Variable 4 Axial Distribution

This card is optional and may only be used if the RBMK or USER feedback options have been specified as W2 on Card 30000000. The axial distribution of user variable 4 is specified in sequential expansion format as pairs of values, the first number representing a weighting factor and the second number representing the axial levels to which the weighting factor should be applied. If this card is input, only one figure of the values of user variable 4 is allowed in the input deck.

W1(R) Weighting factor.

W2(I) Kinetics axial mesh interval number.

....

12.17.13 Cards 30010901 through 30010999, Assignment of User Variable 4 Figures to Axial Mesh Intervals

These cards are optional and may only be entered if the RBMK or USER feedback options have been specified as W2 on Card 30000000. These cards may not be entered if Card 30010900 is entered and vice-versa. Figures of user variable 4 are assigned to axial mesh intervals (x-y planes) starting from the bottom and extending to the top of the core using sequential expansion format. There are no restrictions on the assignment of figures of user variable 1 to mesh intervals.

W1(I) User variable 4 figure number. A user variable 4 figure number must be greater than zero and less than 100.

W2(I) Kinetics axial mesh interval number.

....

12.17.14 Cards 3002ZZ01 through 3002ZZ99, Assignment of Zones to Zone Figures

Thermal-hydraulic zones are assigned to kinetics nodes in zone figure ZZ (at each axial mesh x-y plane) starting from the upper left hand corner of the zone figure and proceeding to the right across each row in succession from the top row to the bottom row of kinetics nodes in the zone figure. There are no restrictions on the assignment of zones to kinetics nodes. All kinetics nodes in the zone figure must be assigned a zone number. A thermal-hydraulic zone number of zero means that the kinetics node is not included in the kinetics solution domain. The zeros in the zone figures must be assigned to the same locations in each zone figure. See Section 4.9 of this appendix for the layout of kinetics nodes in a zone figure.

W1(I) Zone number for first kinetics node. A zone number must be less than 10000.

W2(I) Zone number for second kinetics node.

W3(I) Zone number for third kinetics node.

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12.17.15 Cards 3003CC01 through 3003CC99, Assignment of Compositions to Composition Figures

Compositions are assigned to kinetics nodes in composition figure CC (at each axial mesh x-y plane) starting from the upper left hand corner of the composition figure and proceeding to the right across each row in succession from the top row to the bottom row of kinetics nodes in the composition figure. There are no restrictions on the assignment of compositions to kinetics nodes. A composition number of zero means that the kinetics node is not included in the kinetics solution domain. The zeros in the composition figures must be consistent with the zeros in the first zone figure.

W1(I) Composition number for first kinetics node. A composition number must be less than 1000.

W2(I) Composition number for second kinetics node.

W3(I) Composition number for third kinetics node.

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12.17.16 Cards 3004MMMM, Assignment of Control Rod Groups to Kinetics Nodes

Control rod groups are assigned to node MMMM on an axial plane and the assignment is the same for all axial planes in the model. There are no restrictions on the assignment of rod groups to nodes and a rod group may be associated with more that one node.

W1(I) Identification number of first control rod group in kinetics node MMMM.

W2(I) Identification number of second control rod group in kinetics node MMMM.

12.17.17 Card 300500000, Kinetics Axial Plane Initial Power Distribution

This card is optional, and contains the initial guess for the prompt fission power distribution in the axial plane. The axial distribution of power is specified in sequential expansion format as pairs of values, the first value representing the fraction of the total prompt fission power generated in the kinetics nodes in the axial plane and the second value representing the axial level to which the power fraction should be applied. The prompt fission power specified for each axial plane is apportioned equally to all kinetics nodes in the plane (i.e., a flat radial power distribution in the x-y plane). If this card is input, cards 3005PPXX, specification of node initial power distribution for each kinetics node, and cards 300500XX, specification of the initial power distribution for each zone are not entered.

W1(R) Fraction of total fission power deposited in the axial mesh plane.

W2(I) Identification number of the axial plane.

12.17.18 Cards 30050001 through 30050099, Zone Initial Power Distribution

These cards are optional and contain the initial guess for the power distribution in the zones. A uniform power distribution is assumed if the cards are not entered. The data consists of pairs of data items, the first data item being the identification number of a zone and the second item being the fraction of the total reactor power (sum of fission and decay powers) which is deposited in the zone. A pair of data items must be entered for each zone specified in the zone figures but the zones may be entered in any order.

W1(I) Identification number of zone.

W2(R) Fraction of total reactor power deposited in the zone.

12.17.19 Cards 3005PP01 through 3005PP99, Kinetics Node Initial Power Distribution Figures

These cards are optional and contail the initial guess for the prompt fission power distribution for each kinetics node. Values are specified for each kinetics node in axial plane PP (PP must be greater than zero and less than or equal to the number of axial planes in the kinetics mesh) (Word 1 of Card 30000003) starting from the upper left hand corner of the mesh and proceeding to the right across each row in succession from the top row to the bottom row of kinetics nodes in the mesh plane. The values specify the fraction of total prompt fission power generated in each kinetics node and must be greater than or equal to zero or equal to the value specified in Word 18 of Card 30000003. A input value equal to the value of Word 18 on Card 30000003 means that the node is not included in the kinetics solution domain. This value in not allowed in the interior of the solution domain. If these cards are input, card 30050000 and cards 30050001 through 30050099 are not input. The pattern of nodes with a value equal to the value of Word 18 on Card 30000003 in the power distributions must be consistent with the pattern of zeros in the first zone figure.

W1(R) Fraction of total fission power for first kinetics node.

W2(R) Fraction of total fission power for second kinetics node.

W3(R) Fracion of total fission power for third kinetics node.

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12.17.20 Cards 3006UU01 through 3006UU99, User Variable 1 Figures

These cards are allowed if the RBMK or USER feedback options have been specified as W2 on Card 30000000. Values of user variable 1 are specified for each kinetics node in user variable 1 figure UU (figure identifier UU must be greater than or equal to 1 and less than or equal to 99) starting from the upper left hand corner of the figure and proceeding to the right across each row in succession from the top row to the bottom row of kinetics nodes in the figure. A value equal to the value of Word 18 on Card 30000003 designates that the node is not part of the kinetics solution domain. This value is not allowed in the interior of the solution domain. If the axial distribution of user variable 1 has been specified using Card 30010600, only one figure of user variable 1 is allowed. If figures of user variable 1 have been assigned to the axial mesh planes using Cards 30010601 through 30010699, one or more figures are allowed. The pattern of nodes with a value equal to the value of Word 18 on Card 30000003 must be consistent with the pattern of zeros in the first zone figure.

W1(R) Value of user variable 1 for first kinetics node.

W2(R) Value of user variable 1 for second kinetics node.

W3(R) Value of user variable 1 for third kinetics node.

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12.17.21 Cards 3007UU01 through 3007UU99, User Variable 2 Figures

These cards are allowed if the RBMK or USER feedback options have been specified as W2 on Card 30000000. Values of user variable 2 are specified for each kinetics mesh in user variable 2 figure UU (figure identifier UU must be greater than or equal to 1 and less than or equal to 99) starting from the upper left hand corner of the figure and proceeding to the right across each row in succession from the top row to the bottom row of kinetics nodes in the figure. A value equal to the value of Word 18 on Card 30000003 designates that the node in not part of the kinetics solution domain. This value is not allowed in the interior of the solution domain. If the axial distribution of user variable 2 has been specified using Card 30010700, only one figure of user variable 2 is allowed. If figures of user variable 2 have been assigned to the axial mesh planes using Cards 30010701 through 30010799, one or more figures are allowed. The pattern of nodes with a value equal to the value of Word 18 on Cards 30000003 must be consistent with the pattern of zeros in the first zone figure.

W1(R) Value of user variable 2 for first kinetics node.

W2(R) Value of user variable 2 for second kinetics node.

W3(R) Value of user variable 2 for third kinetics node.

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12.17.22 Cards 3008UU01 through 3008UU99, User Variable 3 Figures

These cards are allowed if the RBMK or USER feedback options have been specified as W2 on Card 30000000. Values of user variable 3 are specified for each kinetics mesh in user variable 3 figure UU (figure identifier UU must be greater than or equal to 1 and less than or equal to 99) starting from the upper left hand corner of the figure and proceeding to the right across each row in succession from the top row to the bottom row of kinetics nodes in the figure. A value equal to the value of Word 18 on Cards 30000003 designates that the node is not part of the kinetics solution domain. This value is not allowed in the interior of the solution domain. If the axial distribution of user variable 1 has been specified using Card 30010800, only one figure of user variable 3 is allowed. If figures of user variable 3 have been assigned to the axial mesh planes using Cards 30010801 through 30010899, one or more figures are allowed. The pattern of nodes with a value equal to the value of Word 18 on Card 3000003 must be consistent with the pattern of zeros in the first zone figure.

W1(R) Value of user variable 3 for first kinetics node.

W2(R) Value of user variable 3 for second kinetics node.

W3(R) Value of user variable 3 for third kinetics node.

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12.17.23 Cards 3009UU01 through 3009UU99, User Variable 4 Figures

These cards are allowed if the RBMK or USER feedback options have been specified as W2 on Card 30000000. Values of user variable 4 are specified for each kinetics node in user variable 4 figure UU (figure identifier UU must be greater than or equal to 1 and less than or equal to 99) starting from the upper left hand corner of the figure and proceeding to the right across each row in succession from the top row to the bottom row of kinetics nodes in the figure. A value equal to the value of Word 18 on Card 30000003 designates that the node is not part of the kinetics solution domain. This value is not allowed in the interior of the solution domain. If the axial distribution of user variable 4 has been specified using Card 30010900, only one figure of user variable 4 is allowed. If figures of user variable 4 have been assigned to the axial mesh planes using Cards 30010901 through 30010999, one or more figures are allowed. The pattern of nodes with a value equal to the value of Word 18 on Card 30000003 must be consistent with the pattern of zeros in the first zone figure.

W1(R) Value of user variable 4 for first kinetics node.

W2(R) Value of user variable 4 for second kinetics node.

W3(R) Value of user variable 4 for third kinetics node.

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12.17.24 Cards 30100001 through 30100099, Bundle Rotation Figure

These cards are optional. The values specify the angle of rotation of the bundle relative to the orientation specified as part of the composition coefficients. Values are entered starting from the upper left hand corner of the figure and proceeding to the right across each row in succession for the top row to the bottom row. Values equal to the value of Word 18 on Cards 30000003 are ignored and signify that the mesh box is not part of the computational domain. The pattern of values equal to the value of Word 18 on Card 30000003 must be consistant with the pattern of zeros in the first zone figure. The rotations are clockwise rotations when viewed from the top of the kinetics mesh and are applied to the discontinuity factors for the composition specified in each mesh location. The allowed values for Cartesain geometry are 0.0, 90.0, 180.0, and 270.0. The allowed values for hexagonal geometry are 60.0, 120.0, 180.0, 240.0, and 300.0. Default values are zero. A rotation of 90.0 degrees means that the discontinuity factor specified for the y+ direction in the composition coefficients is applied to the x+ direction, the discontinuity factor specified for the x+ direction in the composition coefficients is applied to the y- direction, the factor specified for the y- direction in the composition coefficients is applied to the x- direction, and the factor specified for the x- direction is applied to the y+ direction. Similar rotations are applied for hexagonal geometry where the u+ discontinuity factor is applied to the x+ direction, etc.

W1(R) Rotation angle for first kietics mesh

W2(R) Rotation angle for the second kinetics mesh

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12.17.25 Neutron Cross-Section Data for RAMONA Option

The following cards are input if the RAMONA neutron cross-section option is specified as Word 2 of Card 30000000.

12.17.25.1 Cards 31ZZZZ101 through 31ZZZZ199, Volume Feedback Factors. These cards assign hydrodynamic volumes to zone ZZZZ for computing averaged properties needed to compute cross-section information for the one-dimensional steady-state and kinetics advancement using the RAMONA option. The hydrodynamic volumes in this zone should be at the same axial levels as the kinetic mesh intervals in this zone. Each volume is usually in just one axial level, but volumes in contiguous axial levels can be entered. If the hydrodynamic mesh uses more than the axial dimension to represent the core, volumes in the horizontal plane but in the same axial levels may be entered. The above are recommendations. The input allows any hydrodynamic volume to be entered in any zone but volumes may not appear in more than one zone. Quadruplets of words are entered as needed.

W1(I) Volume number.

W2(R) Volume weighting factor for average void fraction.

W3(R) Volume weighting factor for average fluid temperature.

W4(R) Volume weighting factor for average poison concentration.

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12.17.25.2 Cards 31ZZZZ201 through 31ZZZZ299, Heat Structure Feedback Factors. These cards assign heat structures to zone ZZZZ for computing averaged properties needed to compute cross-section information using the RAMONA option. The assigned heat structures are usually connected to the hydrodynamic volumes assigned to the same zone on Cards 31ZZZZ101 through 31ZZZZ199. However the input allows any heat structure to be entered. Pairs of words are entered as needed.

W1(I) Heat structure number.

W2(R) Heat structure weighting factor.

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12.17.25.3 Card 320000000, Temperature Units. This card contains the temperature units code. The units code indicates the units of the reference temperatures. If this quantity is 1, the units are K, if 2, the units are ^{o}C, if 3, the units are ^{o}R, and if 4, the units are ^{o}F.

W1(I) Reference temperature units code. Default = 1.

12.17.25.4 Card 320000001, Composition Card Type. This card is optional and specifies, if present, the card number format for the composition data cards. The default format is 32CCCXXXX. This format allows up to 999 compositions (CCC) to be entered on the composition cards. The alternate card number format, 32CCCCXXX allows up to 9999 compositions (CCCC) to be entered on the composition cards.

W1(I) Enter 999 for card number format 32CCCXXXX or 9999 for card number format 32CCCCXXX.

12.17.25.5 Cards 32CCC0000 or 32CCCC000, Composition Reference Data. These cards contain the neutron yields and the reference temperatures.

W1(R) Moderator reference temperature. Default = 273.16 K.

W2(R) Fuel reference temperature. Default = 273.16 K.

W3(R) Group 1 neutron yield. Default = 2.5.

W4(R) Group 2 neutron yield. Default = 2.5.

W5(R) Group 3 neutron yield. Default = 2.5.

W6(R) Group 4 neutron yield. Default = 2.5.

12.17.25.6 Cards 32CCC0GN1 through 32CCC0GN9, Composition Coefficient Data. The nine factors defining cross-section type N in group G for composition CCC and the discontinuity factors for each face and group are entered on these cards. If data for a composition number are entered but not referenced on Cards 32CCCC0000, the data are read and checked but discarded. The units for each cross-section are denoted by the symbol U. Group 1 is the fast group and group 2 is the thermal group.

<u>N</u>	<u>Cross-section type.</u>
1	Group diffusion coefficient. These cross sections are required for each neutron group (U_1 = cm).
2	Group macroscopic absorption cross-section. These cross sections are required for each neutron group (U_2 = cm^{-1}).
3	Group macroscopic fission cross-section. These cross sections are optional. Defaults values are zero (U_3 = cm^{-1}).
4	Group buckling. These parameters are optional. Defaults values are zero (U_4 = cm^{-2}).
5-7	Group macroscopic scattering cross-sections from group j into group g; j = 1,ng; $j \neq g$. These cross sectional are optional. Default values are zero (U_5 = cm^{-1}).
W1(R)	a_1.
W2(R)	a_2.
W3(R)	a_3.
W4(R)	a_4.
W5(R)	a_5.
W6(R)	a_6.
W7(R)	a_7.
W8(R)	a_8.
W9(R)	a_9.

<u>N</u> <u>Cross-section type.</u>

8 Group discontinuity factors. These parameters are optional. Default values are one (U_8=-). (Six or eight doublets for Cartesian and hexagonal geometry respectively, each doublet representing the uncontrolled and controlled discontinuity factors for a node face, the faces being ordered y+,x+,y-,x-,z+,z- (i.e., N, E, S, W, UP, DOWN) for Cartesian geometry and u+,x+,v-,u-,x-,v+,z+,z- (i.e., NE, E, SE, SW, W, NW, UP, DOWN in **Figure 7.2-1** of Volume I) for hexagonal geometry.

W1(R) Discontinuity factor for face 1 (uncontrolled).

W2(R) Discontinuity factor for face 1 (controlled).

W3(R) Discontinuity factor for face 2 (uncontrolled).

W4(R) Discontinuity factor for face 2 (controlled).

W5(R) Discontinuity factor for face 3 (uncontrolled).

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12.17.26 Neutron Cross-Section Data for HWR Option

The following cards are entered if the HWR option is specified as W2 of Card 30000000.

12.17.26.1 Card 310000000, Volume and Heat Structure Feedback Region Data. The number of volume regions and the number of heat structure regions in the neutron cross-section function for the HWR option are entered on this card.

W1(I) Number of volume feedback regions.

W2(I) Number of heat structure feedback regions.

12.17.26.2 Cards 31ZZZZ1N1 through 31ZZZZ1N9, Volume Feedback Weighting Factors. These cards assign volumes to volume feedback region N of zone ZZZZ. Volume feedback region variables are volume average fluid density, volume average fluid temperature, and volume average poison density. Quadruplets of numbers are entered as needed. The value of N varies from 1 up to and including the value of W1 on Card 310000000.

W1(I) Volume number.

W2(R) Volume weighting factor for average fluid density.

W3(R) Volume weighting factor for average fluid temperature.

W4(R) Volume weighting factor for average poison concentration.

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12.17.26.3 Cards 31ZZZZ2N1 through 31ZZZZ2N9, Heat Structure Feedback Weighting Factors. These cards assign heat structures to heat structure feedback region N of zone ZZZZ. The value of N varies from 1 up to and including the value of W2 on Card 310000000. The assigned heat structure are usually connected to the hydrodynamic volumes assigned to the same region in the same zone in Cards 31ZZZZ1N1 through 31ZZZZ1N9. However the input allows any heat structure to be entered.

W1(I) Heat structure number.

W2(R) Heat structure weighting factor.

12.17.26.4 Card 320000001, Composition Card Type. This card is optional and specifies, if present, the card number format for the composition data cards. The default format is 32CCCXXXX. This format allows up to 999 compositions (CCC) to be entered on the composition cards. The alternate card number format, 32CCCCXXX allows up to 9999 compositions (CCCC) to be entered on the composition cards.

W1(I) Enter 999 for card number format 32CCCXXXX or 9999 for card number format 32CCCCXXX.

12.17.26.5 Cards 32CCC0000 or 32CCCC000, Composition Neutron Yield Data. This card contains the neutron yields for composition CCC or composition CCCC.

W1(R) Group 1 neutron yield. Default = 2.5.

W2(R) Group 2 neutron yield. Default = 2.5.

W3(R) Group 3 neutron yield. Default = 2.5.

W4(R) Group 4 neutron yield. Default = 2.5.

12.17.26.6 Cards 32CCC0GN1 through 32CCC0GN9 or Card 32CCCC0GN, Neutron Base Cross-Section Data. These cards contain the base controlled and uncontrolled neutron cross-sections for cross-section type N in group G for composition CCC or composition CCCC. The units for each of the cross-sections is denoted by the symbol U.

<u>N</u> <u>Cross-section type.</u>

1 Group diffusion coefficient. These cross sections are required for each neutron group (U_1 = cm).

2 Group macroscopic absorption cross-section. The cross sections are required for each neutron group (U_2 = cm^{-1}).

3 Group macroscopic fission cross-section. These cross sections are optional. Defaults values are zero (U_3 = cm^{-1}).

4 Group buckling. These parameters are optional. Default values are zero (U_4 = cm^{-2}).

5-7 Group macroscopic scattering cross-sections from group j into group g; j=1, ng; $j \neq g$. These cross sections are optional. Default values are zero (U_5 = cm^{-1}).

W1(R) Base uncontrolled cross-section value (U_n).

W2(R) Base controlled cross-section value (U_n).

<u>N</u> <u>Cross-section type.</u>

8 Group discontinuity factors. These parameters are optional. Default values are one (U_8=-). (Six or eight doublets for Cartesian and hexagonal geometry respectively each doublet representing the uncontrolled and controlled discontinuity factors for a node face, the faces being ordered y+,x+,y-,x-,z+,z- (i.e., N, E, S, W, UP, DOWN) for Cartesian geometry and u+,x+,v-,u-,x-,v+,z+,z- (i.e., NE, E, SE, SW, W, NW, UP, DOWN in **Figure 7.2-1** of Volume I) for hexagonal geometry.

W1(R) Discontinuity factor for face 1 (uncontrolled).

W2(R) Discontinuity factor for face 1 (controlled).

W3(R) Discontinuity factor for face 2 (uncontrolled).

W4(R) Discontinuity factor for face 2 (controlled).

W5(R) Discontinuity factor for face 3 (uncontrolled).

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12.17.26.7 Cards 32CCC1GN1 through 32CCC1GN9 or Card 32CCCC1GN, Volume Region Temperature Data. These cards are optional for each cross section and buckling parameter and must not be entered for group discontinuity factors. Group discontinuity factors are only a function of control rod position. The cards contain the coefficients and reference temperatures for the volume region temperature terms in the neutron cross-section function for neutron cross-section N in group G for composition CCC or composition CCCC. Pairs of data are entered and the number of pairs must be equal to W1 on Card 310000000. Default values are zero.

W1(R) First volume region temperature coefficient (1/K).

W2(R) First volume region temperature reference value (K).

W3(R) Second volume region temperature coefficient (1/K).

W4(R) Second volume region temperature reference value (K).

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12.17.26.8 Cards 32CCC2GN1 through 32CCC2GN9 or Card 32CCCC2GN, Volume Region Poison Concentration Data. These cards are optional for each cross section and buckling parameter and must not be entered for group discontinuity factors. Group discontinuity factors are only a function of control rod position. The cards contain the coefficient and reference poison density for the volume region poison density terms in the neutron cross-section function for neutron cross-section N in group G for composition CCC or composition CCCC. Pairs of data are entered and the number of pairs must be equal to W1 on Card 310000000. Default values are zero.

W1(R) First volume region poison concentration coefficient (1/ppm).

W2(R) First volume region poison concentration reference value (ppm).

W3(R) Second volume region poison concentration coefficient (1/ppm).

W4(R) Second volume region poison concentration reference value (ppm).

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12.17.26.9 Cards 32CCC3GN1 through 32CCC3GN9 or Card 32CCCC3GN, Volume Region Fluid Density Data. There cards are optional for each neutron cross section and buckling parameter and must not be entered for group discontinuity factors. Group discontinuity factors are only a function of control rod position. The cards contain the linear and quadratic coefficients and the reference fluid density for the volume region fluid density terms in the neutron cross-section function for cross-section N in group G for composition CCC or composition CCCC. Triplets of data are entered and the number of triplets must be equal to Word 1 on Card 30100000. Default values are zero.

W1(R) First volume region fluid density linear coefficient [1/ (kg/m^3)].

W2(R) First volume region fluid density quadratic coefficient [1/(kg/m^3)^2].

W3(R) First volume region fluid density reference value (kg/m^3).

W4(R) Second volume region fluid density linear coefficient [$1/(kg/m^3)$].

W5(R) Second volume region fluid density quadratic coefficient [$1/(kg/m^3)^2$].

W6(R) Second volume region fluid density reference value (kg/m^3).

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12.17.26.10 Cards 32CCC4GN1 through 32CCC4GN9 or Card 32CCCC4GN, Heat Structure Region Temperature Data. These cards are optional for each cross section and buckling parameter and must not be entered for group discontinuity factors. Group discontinuity factors are only a function of control rod position. The cards contain the coefficients and reference temperatures for the heat structure region temperature terms in the neutron cross-section function for neutron cross-section N in group G for composition CCC or composition CCCC. Pairs on values are entered and the number of pairs must equal W2 on Card 310000000. Default values are zero.

W1(R) First heat structure region coefficient (1/K).

W2(R) First heat structure region reference value (K).

W3(R) Second heat structure region coefficient (1/K).

W4(R) Second heat structure region reference value (K).

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12.17.27 Neutron Cross-Section Data for GEN Option

The following cards are entered if the GEN option is specified as W2 of Card 30000000

12.17.27.1 Card 310000000, Volume and Heat Structure Feedback Region Data. The number of volume regions and the number of heat structure regions in the neutron cross-section function for the GEN option are entered on this card.

W1(I) Number of volume feedback regions.

W2(I) Number of heat structure feedback regions.

12.17.27.2 Cards 31ZZZZ1N1 through 31ZZZZ1N9, Volume Feedback Weighting Factors. These cards assign volumes to volume feedback region N of zone ZZZZ. Volume feedback region variables are volume average fluid density/void fraction, volume average fluid temperature, and volume average poison density. Pairs of numbers are entered as needed. The value of N varies from 1 up to and including the value of W1 on Card 310000000.

W1(I) Volume number.

W2(R) Volume weighting factor for average fluid density/void fraction.

W3(R) Volume weighting factor for average fluid temperature.

W4(R) Volume weighting factor for average poison density.

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12.17.27.3 Cards 31ZZZZ2N1 through 31ZZZZ2N9, Heat Structure Feedback Weighting Factors. These cards assign heat structures to heat structure feedback region N of zone ZZZZ. The value of N varies from 1 up to and including the value of W2 on Card 31000000.The assigned heat structures are usually connected to the hydrodynamic volumes assigned to the same region in the same zone in Cards 31ZZZZ1N1 through 31ZZZZ1N9. However the input allows any heat structure to be entered.

W1(I) Heat structure number.

W2(R) Heat structure weighting factor.

12.17.27.4 Card 320000000, GEN Options. This card contains the temperature units code, the density/void fraction variable flag, the structure temperature power flag, and the diffusion coefficient/transport cross-section flag. The units code indicates the units of the reference temperatures. If this quantity is 1, the units are K, if 2, the units are ^{o}C, if 3, the units are ^{o}R, and if 4, the units are ^{o}F. The density/void fraction variable flag indicates whether the density/void fraction variable in the neutron cross-section formulation is the mixture density (flag = 0) or the fluid void fraction (flag = 1). The structure temperature power flag indicates whether the temperature (flag = 0) or the square root of the temperature (flag = 1) is used in the neutron cross-section formulation. The diffusion coefficient/transport cross-section flag determines whether the diffusion coefficient (flag = 0) or the transport cross-section (flag = 1) is entered.

W1(I) Reference temperature units code. Default = 1.

W2(I) Density/void fraction variable flag. Default = 0.

W3(I) Structure temperature power flag. Default = 0.

12.17.27.5 Card 320000001, Composition Card Type. This card is optional and specifies, if present, the card number format for the composition data cards. The default format is 32CCCXXXX. This format allows up to 999 compositions (CCC) to be entered on the composition cards. The alternate card number format, 32CCCCXXX allows up to 9999 compositions (CCCC) to be entered on the composition cards.

W1(I) Enter 999 for card number format 32CCCXXXX or 9999 for card number format 32CCCCXXX.

W4(I) Diffusion coefficient/transport cross section flag. Default = 0.

12.17.27.6 Card 32CCC0000 or Card 32CCCC000, Composition Neutron Yield Data. This card contains the neutron yields for composition CCC or composition CCCC.

W1(R) Group 1 neutron yield. Default = 2.5.

W2(R) Group 2 neutron yield. Default = 2.5.

W3(R) Group 3 neutron yield. Default = 2.5.

W4(R) Group 4 neutron yield. Default = 2.5.

12.17.27.7 Cards 32CCC0GN1 through 32CCC0GN9 or Card 32CCCC0GN, Neutron Base Cross-Section Data. These cards contain the base uncontrolled, controlled, and driver neutron cross-sections for neutron cross-section N in group G for composition CCC or composition CCCC. The units for each of the cross-sections is denoted by the symbol U.

N Cross-section type.

1 Group diffusion coefficient/group macroscopic transport cross section. These cross sections are required for each neutron group (U_1 = cm)/(U_1 = cm^{-1}).

2 Group macroscopic absorption cross-section. These cross sections are required for each neutron group (U_2 = cm^{-1}).

3 Group macroscopic fission cross-section. These cross sections are optional. Default values are zero (U_3 = cm^{-1}).

4 Group buckling. These parameters are optional. Default values are zero (U_4 = cm^{-2}).

5-7 Group macroscopic scattering cross-sections from group j into group g; j = 1, ng; $j \neq g$. These cross sections are optional. Defaults values are zero (U_5 = cm^{-1}).

W1(R) Base uncontrolled cross-section value (U_n).

W2(R) Base active controlled cross-section value (U_n).

W3(R) Base driver controlled cross-section value (U_n).

N	Cross-section type.
8	Group discontinuity factors. These parameters are optional. Default values are one (U_8=-). (Six or eight triplets for Cartesian and hexagonal geometry respectively, each triplet representing the uncontrolled, active controlled and driver controlled discontinuity factors for a node face, the faces being ordered y+,x+,y-,x-,z+,z- (i.e., N, E, S, W, UP, DOWN) for Cartesian geometry and u+,x+,v-,u-,x-,v+,z+,z- (i.e., NE, E, SE, SW, W, NW, UP, DOWN in **Figure 7.2-1** of Volume I) for hexagonal geometry.

W1(R) Discontinuity factor for face 1 (uncontrolled).

W2(R) Discontinuity factor for face 1 (controlled).

W3(R) Discontinuity factor for face 2 (uncontrolled).

W4(R) Discontinuity factor for face 2 (controlled).

W5(R) Discontinuity factor for face 3 (uncontrolled).

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12.17.27.8 Cards 32CCC1GN1 through 32CCC1GN9 or Card 32CCCC1GN, Volume Region Temperature Data. These cards are optional for each cross section and buckling parameter and must not be entered for group discontinuity factors. Group discontinuity factors are only a function of control rod position. The cards contain the coefficients and reference temperatures for the volume region temperature terms in the neutron cross-section function for neutron cross-section N in group G of composition CCC or composition CCCC. Quadruplets of data are entered and the number of quadruplets must be equal to W1 on Card 310000000. Default values are zero.

W1(R) First volume region uncontrolled temperature coefficient (1/K).

W2(R) First volume region active controlled temperature coefficient (1/K).

W3(R) First volume region driver controlled temperature coefficient (1/K).

W4(R) First volume region temperature reference value (K).

W5(R) Second volume region uncontrolled temperature coefficient (1/K).

W6(R) Second volume region active controlled temperature coefficient (1/K).

W7(R) Second volume region driver controlled temperature coefficient (1/K).

W8(R) Second volume region temperature reference value (K).

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12.17.27.9 Cards 32CCC2GN1 through 32CCC2GN9 or Card 32CCCC2GN, Volume Region Poison Concentration Data. These cards are optional for each cross section and buckling parameter and must not be entered for group discontinuity factors. Group discontinuity factors are only a function of control rod position. The cards contain the coefficient and reference poison density for the volume region poison density terms in the neutron cross-section function for neutron cross-section N in group G for composition CCC or composition CCCC. Quadruplets of data are entered and the number of quadruplets must be equal to W1 on Card 310000000. Default values are zero.

W1(R) First volume region uncontrolled poison concentration coefficient (1/ppm).

W2(R) First volume region active controlled poison concentration coefficient (1/ppm).

W3(R) First volume region driver controlled poison concentration coefficient (1/ppm).

W4(R) First volume region poison concentration reference value (ppm).

W5(R) Second volume region uncontrolled poison concentration coefficient (1/ppm).

W6(R) Second volume region active controlled poison concentration coefficient (1/ppm).

W7(R) Second volume region driver controlled poison concentration coefficient (1/ppm).

W8(R) Second volume region poison density reference value (ppm).

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12.17.27.10 Cards 32CCC3GN1 through 32CCC3GN9 or Card 32CCCC3GN, Volume Region Fluid Density/Void Fraction Data. These cards are optional for each cross section and buckling parameter and must not be entered for group discontinuity factors. Group discontinuity factors are only a function of control rod position. The cards contain the linear and quadratic coefficients and the reference fluid density/void fraction for the volume region fluid density/void fraction terms in the neutron cross-section function for neutron cross-section N in group G for composition CCC or composition CCCC. Septuplets of data are entered and the number of septuplets must be equal to Word 1 on Card 310000000. Default values are zero.

W1(R) First volume region uncontrolled fluid density/void fraction linear coefficient [1/(kg/m^3)].

W2(R) First volume region active controlled fluid density/void fraction linear coefficient [1/(kg/m^3)].

W3(R) First volume region driver controlled fluid density/void fraction linear coefficient [1/(kg/m^3)].

W4(R) First volume region uncontrolled fluid density/void fraction quadratic coefficient $[1/(kg/m^3)^2]$.

W5(R) First volume region active controlled fluid density/void fraction quadratic coefficient $[1/(kg/m^3)^2]$.

W6(R) First volume region driver controlled fluid density/void fraction quadratic coefficient $[1/(kg/m^3)^2]$.

W7(R) First volume region fluid density/void fraction reference value (kg/m^3).

W8(R) Second volume region uncontrolled fluid density/void fraction linear coefficient $[1/(kg/m^3)]$.

W9(R) Second volume region active controlled fluid density/void fraction linear coefficient $[1/(kg/m^3)]$.

W10(R) Second volume region driver controlled fluid density/void fraction linear coefficient $[1/(kg/m^3)]$.

W11(R) Second volume region uncontrolled fluid density/void fraction quadratic coefficient $[1/(kg/m^3)^2]$.

W12(R) Second volume region active controlled fluid density/void fraction quadratic coefficient $[1/(kg/m^3)^2]$.

W13(R) Second volume region driver controlled fluid density/void fraction quadratic coefficient $[1/(kg/m^3)^2]$.

W14(R) Second volume region fluid density/void fraction reference value (kg/m^3).

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12.17.27.11 Cards 32CCC4GN1 through 32CCC4GN9 or Card 32CCCC4GN, Heat Structure Region Temperature Data. These cards are optional for each cross section and buckling parameter and must not be entered for group discontinuity factors. Group discontinuity factors are only a function of control rod position. The cards contain the coefficients and reference temperatures for the heat structure region temperature terms in the neutron cross-section function for neutron cross-section N in group G for composition CCC or composition CCCC. Quadruplets of values are entered and the number of quadruplets must equal W2 on Card 310000000. Default values are zero.

W1(R) First heat structure region uncontrolled temperature coefficient (1/K).

W2(R) First heat structure region active controlled temperature coefficient (1/K).

W3(R) First heat structure region driver controlled temperature coefficient (1/K).

W4(R) First heat structure region temperature reference value (K).

W5(R) Second heat structure region uncontrolled temperature coefficient (1/K).

W6(R) Second heat structure region active controlled temperature coefficient (1/K).

W7(R) Second heat structure region driver controlled temperature coefficient (1/K).

W8(R) Second heat structure region temperature reference value (K).

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12.17.27.12 Card 340000000, Xenon/Samarium Decay Constants. This card is optional***.*** The card contains the decay constants for iodine, xenon, and promethium.

W1(R) Decay constant for ^{135}I. Default = 2.929985x10^{-5} (1/sec).

W2(R) Decay constant for ^{135}Xe. Default = 2.115385x10^{-5} (1/sec).

W3(R) Decay constant for ^{149}Pm. Default = 3.626055x10^{-6} (1/sec).

12.17.27.13 Cards 34CCC0000 or Card 34CCCC000, Composition Xenon/Samarium Fission Yield Data. These cards are optional***.*** The cards contain the neutron yields for the important isotopes in the Xenon and Samarium decay chains.

W1(R) Fission yield for ^{135}I. Default = 0.063.

W2(R) Fission yield for ^{135}Xe. Default = 0.0007549.

W3(R) Fission yield for ^{149}Pm. Default = 0.01067.

W4(R) Fission yield for ^{149}Sm. Default = 0.0.

12.17.27.14 Cards 34CCC0GN1 through 34CCC0GN9 or Card 34CCCC0GN, Xenon/Samarium Neutron Base Cross-Section Data. These cards contain the base controlled and uncontrolled neutron cross-sections for neutron cross-section type N in group G for composition CCC. The units for each of the cross-sections is barns (1.0 x 10^{-24} cm^{2})

<u>N</u> <u>Cross-section type</u>

1 Group xenon microscopic absorption cross-section.

2 Group samarium microscopic absorption cross-section.

W1(R) Base uncontrolled cross-section value (barns).

W2(R) Base active controlled cross-section value (barns).

W3(R) Base driver controlled cross-section value (barns).

12.17.27.15 Cards 34CCC1GN1 through 34CCC1GN9 or Card 34CCCC1GN Xenon/Samarium Volume Region Temperature Data. These cards contain the coefficients and reference temperatures for the volume region temperature terms in the neutron cross-section function for neutron cross-section N in group G for composition CCC. Quadruplets of data are entered and the number of quadruplets must be equal to Word 1 on Card 310000000.

W1(R) First volume region uncontrolled temperature coefficient (1/K).

W2(R) First volume region active controlled temperature coefficient (1/K).

W3(R) First volume region driver controlled temperature coefficient (1/K).

W4(R) First volume region temperature reference value (K).

W5(R) Second volume region uncontrolled temperature coefficient (1/K).

W6(R) Second volume region active controlled temperature coefficient (1/K).

W7(R) Second volume region driver controlled temperature coefficient (1/K).

W8(R) Second volume region temperature reference value (K).

12.17.27.16 Cards 34CCC2GN1 through 34CCC2GN9 or Card 34CCCC2GN, Xenon/Samarium Volume Region Poison Concentration Data. These cards contain the coefficient and reference poison density for the volume region poison density terms in the neutron cross-section function for neutron cross-section N in group G for composition CCC. Quadruplets of data are entered and the number of quadruplets must be equal to Word 1 on Card 310000000.

W1(R) First volume region uncontrolled poison concentration coefficient (1/ppm).

W2(R) First volume region active controlled poison concentration coefficient (1/ppm).

W3(R) First volume region driver controlled poison concentration coefficient (1/ppm).

W4(R) First volume region poison concentration reference value (ppm).

W5(R) Second volume region uncontrolled poison concentration coefficient (1/ppm).

W6(R) Second volume region active controlled poison concentration coefficient (1/ppm).

W7(R) Second volume region driver controlled poison concentration coefficient (1/ppm).

W8(R) Second volume region poison density reference value (ppm).

12.17.27.17 Cards 34CCC3GN1 through 34CCC3GN9 or Card 34CCCC3GN, Xenon/Samarium Volume Region Fluid Density/Void Fraction Data. There cards contain the linear and quadratic coefficients and the reference fluid density/void fraction for the volume region fluid density/void fraction terms in the neutron cross-section function for neutron cross-section N in group G for composition CCC. Septuplets of data are entered and the number of Septuplets must be equal to Word 1 on Card 310000000.

W1(R) First volume region uncontrolled fluid density/void fraction linear coefficient [1/(kg/m^3)].

W2(R) First volume region active controlled fluid density/void fraction linear coefficient [1/(kg/m^3)].

W3(R) First volume region driver controlled fluid density/void fraction linear coefficient [1/(kg/m^3)].

W4(R) First volume region uncontrolled fluid density/void fraction quadratic coefficient [1/(kg/m^3)^2].

W5(R) First volume region active controlled fluid density/void fraction quadratic coefficient [1/(kg/m^3)^2].

W6(R) First volume region driver controlled fluid density/void fraction quadratic coefficient [1/(kg/m^3)^2].

W7(R) First volume region fluid density/void fraction reference value (kg/m^3).

W8(R) Second volume region uncontrolled fluid density/void fraction linear coefficient [1/(kg/m^3)].

W9(R) Second volume region active controlled fluid density/void fraction linear coefficient [1/(kg/m^3)].

W10(R) Second volume region driver controlled fluid density/void fraction linear coefficient [1/(kg/m^3)].

W11(R) Second volume region uncontrolled fluid density/void fraction quadratic coefficient [1/(kg/m^3)^2].

W12(R) Second volume region active controlled fluid density/void fraction quadratic coefficient [1/(kg/m^3)^2].

W13(R) Second volume region driver controlled fluid density/void fraction quadratic coefficient [1/(kg/m^3)^2].

W14(R) Second volume region fluid density/void fraction reference value (kg/m^3).

12.17.27.18 Cards 34CCC4GN1 through 34CCC4GN9 or Card 34CCCC4GN, Xenon/Samarium Heat Structure Region Temperature Data. These cards contain the coefficients and reference temperatures for the heat structure region temperature terms in the neutron cross-section function for neutron cross-section N in group G for composition CCC. Quadruplets of values are entered and the number of quadruplets must equal Word 2 on Card 310000000.

W1(R) First heat structure region uncontrolled temperature coefficient (1/K).

W2(R) First heat structure region active controlled temperature coefficient (1/K).

W3(R) First heat structure region driver controlled temperature coefficient (1/K).

W4(R) First heat structure region temperature reference value (K).

W5(R) Second heat structure region uncontrolled temperature coefficient (1/K).

W6(R) Second heat structure region active controlled temperature coefficient (1/K).

W7(R) Second heat structure region driver controlled temperature coefficient (1/K).

W8(R) Second heat structure region temperature reference value (K).

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12.17.28 Neutron Cross Section Data for RBMK Option

The following tables list the composition numbers for fuel channels, non-fuel channels, and control rod channels in an RBMK reactor.

Table 12.17-1 Composition numbers for fuel channels.

Description	Composition Number
2.0% enriched fuel	9
2.4% enriched fuel	10
2.0% enriched fuel with Gadolinium	11

Table 12.17-2 Composition numbers for non-fuel channels.

Description	Composition Number
Axial detector channel (cps loop) RBMK 1000	2
Axial detector channel (cps loop) RBMK 1500	3
Water column in fuel channel (mcc loop)	6
Regular additional absorber (mcc loop)	7
Cluster additional absorber (mcc loop)	8
Radial reflector coolant channel	12
Graphite (radial reflector)	20
Void tube in mcc loop	22

Table 12.17-3 Composition number for control rod channels.

Description	Composition Number
Fast acting scram rod	1
Manual control rod 2091	4
Automatic rod	4
Short bottom control rod	5
Manual control rod 2477 (skirt type)	21
Manual control rod cluster rod	23

The following data are entered if the RBMK feedback option is specified as Word 2 on Card 30000000.

12.17.28.1 Card 310000000, Volume and Heat Structure Feedback Region Data. The number of volume regions and the number of heat structure regions in the neutron cross-section function for the USER option are entered on this card.

W1(I) Number of volume feedback regions.

W2(I) Number of heat structure feedback regions.

12.17.28.2 Cards 31ZZZZ1N1 through 31ZZZZ1N9, Volume Feedback Weighting Factors. These cards assign volumes to volume feedback region N of zone ZZZZ. Volume feedback region variables are volume average fluid density/void fraction, volume average fluid temperature, and volume average poison density. Quadruplets of numbers are entered as needed. The value of N varies from 1 up to and including the value of W1 on Card 310000000.

W1(I) Volume number.

W2(R) Volume weighting factor for average fluid density/void fraction.

W3(R) Volume weighting factor for average fluid temperature.

W4(R) Volume weighting factor for average poison density.

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12.17.28.3 Cards 31ZZZZ2N1 through 31ZZZZ2N9, Heat Structure Feedback Weighting Factors. These cards assign heat structures to heat structure feedback region N of zone ZZZZ. The value of N varies from 1 up to and including the value of W2 on Card 31000000.The assigned heat structures are usually connected to the hydrodynamic volumes assigned to the same region in the same zone in Cards 31ZZZZ1N1 through 31ZZZZ1N9. However the input allows any heat structure to be entered.

W1(I) Heat structure number.

W2(R) Heat structure weighting factor.

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12.17.28.4 Card 320000000, RBMK Thermal-hydraulic Options. This card contains the fluid density/void fraction flag and the poison concentration/poison density flag. The fluid density/void fraction flag indicates whether the fluid density/void fraction variable computed in the regions of the zones is the mixture density (flag = 0) or the void fraction (flag = 1). The poison concentration/poison density flag whether the poison variable computed by the code is the poison concentration (flag = 0) in ppm (parts per million) or is the poison density (flag = 1) in kg/m^3**.**

W1(I) Fluid density/void fraction flag. Default = 0.

W2(I) Poison concentration/poison density flag. Default = 0.

12.17.28.5 Card 320000001, RBMK Neutronic Options.

This card contains the information required for the RBMK neutron cross section calculation, including the position of the top of the fuel relative to the bottom of the kinetics mesh and data required for the xenon power correction factors. Words 1 and 2 specify the neutron fission yields for the fast and thermal groups, respectively. Word 3 specifies the distance to the top of the fuel from the bottom of the kinetics mesh. This value is used to calculate the control rod positions relative to each node. Word 4 is a packed word that controls the following three RBMK modeling options: the control rod position reference, the xenon power correction factor, and the units of local burnup. Words 5 and 6 contain data for calculation of the xenon power correction factor, which adjusts the cross-sections for the effects of xenon poisoning. This correction is correlated to the relative power, which is defined as the ratio of the actual kinetics node power to the average power that would be present in the kinetics node if the core were operated at rated power with the rated fuel loading. Calculation of this ratio requires the rated core power (W) and the total fuel volume at this rated core power and rated fuel loading.

The initial value for the xenon power correction factor is specified by inputting a guess for the initial power distribution. This guess is specified on Card 30050000 (the fraction of total core fission power in each axial plane), or Cards 30050001 through 30050099 (the fraction of total core power in each thermal-hydraulics zone), or Cards 3005ZZ01 through 3005ZZ99 (the fraction of total core fission power in each kinetics node). The calculation of the xenon power correction factor is different depending on the problem option specified on Card 100. If the problem option is STDY-ST, the initial power distribution guess, if input, is used to calculate the initial value for the xenon power correction factor, and the xenon power correction factor is updated for each advancement during the simulation. If the problem option is TRNSNT, the initial power distribution is used to calculate the xenon power correction factor, and this value is then considered to be a constant value (i.e., the xenon concentration change is negligible compared to the transient time of the simulation) that is used for the entire simulation. Note that the values of fission power for each kinetics node are written to the file specified by the -N parameter on the command line at the major edit frequency specified on Cards 201 through 299.

W1(R) Neutron fission yield for neutron group 1 (fast group). The default vaule is 2.5.

W2(R) Neutron fission yield for neutron group 2 (thermal group). The default vaule is 2.5.

W3(R) Location of the top of the active fuel relative to the bottom of the kinetics mesh (m, ft). The default location is the top of the kinetics mesh.

W4(I) User options for flags to control rod reference position, xenon power correction factor, input units for burnup, and neutron flux correction. This word has a packed format, and requires a number between 0 and 63. The first bit from the right is the control rod position flag. If set to on (i.e., Word 4 is 1 if the other bits are not set), it indicates that the control rod position reference specified in Cards 3300RRRR is at the top of the kinetics mesh as specified in Word 3 (of Card 32000001). Otherwise, the control rod position reference is the top of the active fuel. Note that if Word 4 is set to 1, the control rod position will be adjusted by the difference between the top of the kinetics mesh and Word 3. If Word 4 is set to zero, no adjustment is made.

The second bit from the right is the xenon power correction factor. If set to on (i.e., Word 4 is 2 if the other bits are not set), it specifies that the xenon power correction factor is to be used. Otherwise the xenon power correction factor is set to 1. Words 5 and 6 are required if the xenon power correction flag is on.

The third bit from the right is the burnup option. If set to on (i.e., Word 4 is 4 if the other bits are not set), specified burnup units are MW-days/fuel assembly. Otherwise, burnup units are MW-days/kg. Burnup values are entered in User Variable 1 (see Cards 30010600, 300106XX, and 3006UUXX).

The fourth bit from the right is the option to specify the neutron flux correction. If set to on (i.e. Word 4 is 8 if the other bits are not set), the neutron flux correction is performed, In this case, detector data are required to be entered (Cards 3200010000, etc.).

The fifth bit from the right specifies which method of neutron flux correction is to be performed. If set to on (i.e., Word 4 is 16 if the other bits are not set), the correction is applied to the local burnup supplied in User Variable 1. If set to off (i.e. Word 4 is zero if the other bits are not set), the correction is applied to the Group 2 fission cross section. In either case, the corrections are output to a file named by the -P parameter on the command line (the default name for this file is “fluxdata”). If the correction is applied to the Group 2 fission cross-section, the file “fluxdata” contains these corrections and the last set of entries in this file should be entered in User Variable 2 (see Cards 30010700, 300107XX, and 3007UUXX) for reading during the subsequest transient calculation.

The sixth bit from the right specifies the information written to file “fluxdata” if the correction is applied to the local burnup. If set to on (i.e., Word 4 is 32 if the other bits are not set), the file “fluxdata” contains the corrected values of the local burnup, seperated into axial and radial components, and the last set of entries in this file should replace the existing entries for burnup in User Variable 1. If set to off (i.e., Word 4 is zero if the other bits are not set), file “fluxdata” contains correction values to the local burnup, and the last set of entries in this file should be entered in User Variable 2 for reading during the subsequent transient calculation. If Word 4 is not entered, the default value is zero.

W5(R) Total volume occupied by the fuel nodes of the kinetics mesh at rated core power and rated fuel loading (cm^3, ft^3).

W6(R) Rated core power (W). This may or may not be the same as the value entered on Card 30000001. If this value is omitted, the value on Card 30000001 is used.

12.17.28.6 Card 320001000, Control Data for Neutron Flux Correction

This card specifies the parameters for the neutron flux correction procedure. It is required if the neutron flux correction is to be used, and is not allowed otherwise. Words 1, 2, and 3 specify the dimensions of the detector flux measurement data. Two types of flux detectors are present. The radial detectors (DKER) have a single data value. Word 1 specifies the number of locations for which the DKER data are specified. The axial detectors (DKEV) have values along the axial plane. Word 2 specifies the number of DKEV detectors for which data are input. Word 3 specifies the number of axial locations for DKEV data. Words 4 through 8 specify the control parameters for the flux correction procedure. Words 4 and 5 specify the minimum and maximum axial node, respectively, where the flux correction is to be performed. Word 6 specifies the maximum permitted amount of the correction (in percent). Word 7 is the control parameter for the flux correction, and Word 8 is the control parameter for the critical eigenvalue adjustment.

W1(I) Number of radial detectors for which data are input.

W2(I) Number of axial detectors for which data are input.

W3(I) Number of data locations for each axial detector. If a positive valus is entered, the axial values for each detector are entered starting at the bottom of the mesh and proceeding upward. If a negative value is entered, the axial values for each detector are entered starting for the top of the mesh and proceeding downward.

W4(I) Minimum axial node for which the correction procedure is to be applied. This value should correspond the the first core node within the neutronics mesh.

W5(I) Maximum axial node for which the correction procedure is to be applied. This value should correspond to the last core node within the neutronics mesh.

W6(I) Maximum amount of correction that is permitted, as a fraction of the initial value. The default value is 0.04 if the correction is applies to the Group 2 fission cross-section, and is 0.10 if the correction is applied to local burnup.

W7(R) Control parameter for flux correction (default is 5.0×10^{-5}).

W8(R) Control parameter for critical eigenvalue adjustment (default is 4.0×10^{-3}).

12.17.28.7 Cards 32001101-320001199, Radial Detector Data

These cards specify the y and x locations for the radial detectors and the associated flux measurement data. Words 1 and 2 are the y and x locations within the neutronics mesh. The data will be normalized to the prompt fission power calculated by the code in the corresponding location of the mesh. Triplets of data must be entered, and the number of these triplets must be equal to Word 1 on Card 320001000.

W1(1) Detector y location.

W2(I) Detector x location.

W3(R) Detector flux value.

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12.17.28.8 Cards 320001201 - 320001299, Axial Detector Positions

These cards specify the y and x locations for the axial detectors. Words 1 and 2 are the y and x locations within the neutronics mesh. Pairs of data are entered, one for each axial detector.

W1(I) Detector y location.

W2(I) Detector x location.

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12.17.28.9 Cards 320001301 - 320001299, Axial Detector Data

Enter the appropriate number of data values for each detector, in the order that the y-x pairs are specified on Cards 320001201 through 320001299. If Word 3 on Card 320001000 is a positive number, the data are entered starting at the bottom of the mesh and proceeding upward. If Word 3 of Card 320001000 is a negative value, the data are entered starting at the top of the mesh and proceeding downward.

W1(R) First datum for the first axial detector.

W2(R) Second datum for the first axial detector.

12.17.29 Neutron Cross Section Data for USER Option

The USER feedback option is not available in the standard release version of the code, because it requires compilation of the user supplied subroutine USERXS. This subroutine contains user-specified neutron cross-section functions. These functions are used instead of the polynomial functions described in the 32CCCXXXX cards used for the RAMONA, HWR, or GEN options, for special cases in which the polynomial representation of neutron cross-sections provided in the standard version of the code are not adequate to describe the variation of the neutron cross-sections with respect to the variations in the thermal-hydraulic conditions in the reactor core. Special arrangements with INEEL are required for acquisition of the ATHENA libraries for linking to the user supplied USERXS subroutine to build an local version of RELAP5-3D that includes the user specified neutron cross-section methodology.

The following data are entered if the USER feedback option is specified as W2 on Card 30000000.

12.17.29.1 Card 310000000, Volume and Heat Structure Feedback Region Data. The number of volume regions and the number of heat structure regions in the neutron cross-section function for the USER option are entered on this card.

W1(I) Number of volume feedback regions.

W2(I) Number of heat structure feedback regions.

12.17.29.2 Cards 31ZZZZ1N1 through 31ZZZZ1N9, Volume Feedback Weighting Factors. These cards assign volumes to volume feedback region N of zone ZZZZ. Volume feedback region variables are volume average fluid density/void fraction, volume average fluid temperature, and volume average poison density. Quadruplets of numbers are entered as needed. The value of N varies from 1 up to and including the value of W1 on Card 310000000.

W1(I) Volume number.

W2(R) Volume weighting factor for average fluid density/void fraction.

W3(R) Volume weighting factor for average fluid temperature.

W4(R) Volume weighting factor for average poison density.

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12.17.29.3 Cards 31ZZZZ2N1 through 31ZZZZ2N9, Heat Structure Feedback Weighting Factors. These cards assign heat structures to heat structure feedback region N of zone ZZZZ. The value of N varies from 1 up to and including the value of W2 on Card 31000000.The assigned heat structures are usually connected to the hydrodynamic volumes assigned to the same region in the same zone in Cards 31ZZZZ1N1 through 31ZZZZ1N9. However the input allows any heat structure to be entered.

W1(I) Heat structure number.

W2(R) Heat structure weighting factor.

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12.17.29.4 Card 320000000, USER Options. This card contains the fluid density/void fraction flag and the poison concentration/poison density flag. The fluid density/void fraction flag indicates whether the fluid density/void fraction variable computed in the regions of the zones is the mixture density (flag = 0) or the void fraction (flag = 1). The poison concentration/poison density flag whether the poison variable computed by the code is the poison concentration (flag = 0) in ppm (parts per million) or is the poison density (flag = 1) in kg/m^3**.**

W1(I) Fluid density/void fraction flag. Default = 0.

W2(I) Poison concentration/poison density flag. Default = 0.

12.18 Control Rod Model Data

These cards contain the data for the control rod model and are only input if the nodal kinetics model has been selected. These cards are optional.

12.18.1 Card 33000000, Global Control Rod Insertion Direction Data

This card is optional. This card specifies the insertion direction of all control rods. Use this card if all rods are inserted from the same face of the reactor.

W1(I) Insertion direction of all control rods. A value of zero means up from the bottom of the reactor core and a value of 1 means down from the top of the reactor core. Default value = 0.

12.18.2 Cards 3300RRRR, Control Rod Group Data

These cards contain data for control rod group RRRR. A control rod group consists of any number of physical control rods that move together, i.e., have the same initial insertion depth and are moved by the same control logic. This grouping can be used to reduce the amount of input data for control rods.

W1(R) Initial insertion depth of control rod group (m, ft). Default = 0.0.

W2(I) Control variable or general table from which the insertion depth of the control rod group is to be determined. The current insertion depth of the control rod group is the sum of the initial insertion depth of the control rod group (Word 1 on this card) and the output of this table or control variable. Note that the output of the table or control variable must be in code internal units, i.e., SI units. A positive value of less than 1000 means the general table with this number is used to determine the insertion depth of the control rod group. If this value is between 10001 and 19999, the insertion depth of the control rod group is determined by the control variable whose identifier is this number minus 10000. A value of 0 specifies that the control rod group does not move and that it remains at its initial insertion depth. Default = 0.

W3(R) Active length of control rod (m, ft). A value of 0.0 denotes a full length control rod. Default = 0.0.

W4(I) Control variable or general table from which the rod worth multiplier for the control rod group is to be determined. A positive value less than 1000 means the general table with this number is used to determine the rod worth multiplier for the control rod group. If this value is between 10001 and 19999, the rod worth multiplier for the control rod group is determined by the control variable whose identifier is the number minus 10000. A value of 0 indicates no rod worth multiplier for the control rod group. Default = 0.

12.18.3 Card 3301RRRR, Control Rod Group Insertion Direction Data

These cards are optional. The value on this card specifies the insertion direction of control rod group RRRR. These cards may not be used if Card 33000000 is used to specify the insertion direction for all of the control rods.

W1(I) Insertion direction of rod group RRRR. A value of zero means up from the bottom of the reactor core and a value of 1 means down from the top of the reactor core. Default = 0.

12.19 Fixed Neutron Source Data

These cards contain the data for the fixed neutron source input and are only input if the nodal kinetics model has been selected.

12.19.1 Cards 35IIJJKKN, Fixed Neutron Source Input Option.

These cards assign neutron sources to node II, JJ, KK in the kinetics model, where II is the row index of the node in the axial plane, JJ is the column index of the node in the axial plane, and KK is the index of the axial plane. If entered, the card must contain a value for each energy group.

W1(R) Source value for the first energy group (neutrons/m^3). Default = 0.0.

W2(R) Source value for the second energy group (neutrons/m^3). Default = 0.0.

W3(R) Source value for the third energy group (neutrons/m^3). Default = 0.0.

W4(R) Source value for the fourth energy group (neutrons/m^3). Default = 0.0.

12.20 Nuclear Detector Model

12.20.1 Card 390DD0000, Detector Data

These cards are only required if a detector is to be modeled.

W1(I) Number of source nodes for detector DD. For nodal kinetics, this can be from 1 to the total number of nodes in the kinetics model. For point kinetics, this is usually 1.

W2(R) Scale factor.

12.20.2 Card 390DDSSS0, Source Data

These cards are required if Card 390DD0000 is present. One card is required for each source SSS.

W1(A) Variable code for the source term.

W2(I) Parameter for the first source term.

W3(R) Weighting factor for the first source term.

W4(I) Number of attenuation terms used in the attenuation model for this source.

12.20.3 Cards 390DDSSS1 through 390DDSSS9, Attenuation Data

These cards are required if Word 4 on Card 390DDSSS0 is greater than zero. The data are input as W4 (on Card 390DDSSS0) sets of four data items. Units conversion is performed for the reference value and the attenuation coefficient based on the independent variable.

W1(A) Variable code for the independent variable in the first attenuation term.

W2(I) Parameter for the independent variable in the first attenuation term.

W3(R) Reference value for the independent variable in the first attenuation term.

W4(R) Attenuation coefficient in the first attenuation term.

W5(A) Variable for the independent variable in the second attenuation term.

W6(I) Parameter for the independent variable in the second attenuation term.

W7(R) Reference value for the independent variable in the second attenuation term.

W8(R) Attenuation coefficient in the second attenuation term.

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13 Cards 20300000 through 20499999, Plot Request Input Data

The plotting capability is not currently active. Besides not being converted to machine-dependent form from the original CDC-176 version, a proprietary plotting package was required. Many users use the strip option to write an ASCII coded STRIPF file containing data to be plotted and interface this file to plotting routines available within their organizations. XMGR could be used to plot data from the STRIPF file. The INEEL usually uses XMGR5, an INEEL extension to XMGR that adds features to conveniently plot information from restart-plot files or STRIPF files.

14 Cards 205CCCNN or 205CCCCN, Control System Input Data

These cards are used in NEW and RESTART problems if a control system is desired. They are also used to define the generic control components employed with the self-initialization option. Input can also be used to compute additional quantities from the normally computed quantities. These additional quantities can then be output in major and minor edits and plots.

Two different card types are available for entering control system data, but only one type can be used in a problem. The digits CCC or CCCC form the control variable number (i.e., control component number). The card format 205CCCNN allows 999 control variables, where CCC ranges from 001 through 999. The card format 205CCCCN allows 9,999 control variables, where CCCC ranges from 0001 through 9999.

If the self-initialization option is selected, the data cards described in Section 14.2, Section 14.3.20, and Section 14.3.21 must be included. If loop flow control is to be included, the data cards described in Section 14.3.19 must also be included.

14.1 Card 20500000, Control Variable

If this card is omitted, card type 205CCCNN is used. If this card is entered, either card format can be selected. This card cannot be entered on RESTART problems if control components exist from the restart problem, in which case the card format from the restart problem must be used.

W1(I) Enter 999 to select the 205CCCNN format or 9999 (4095 also allowed) to select the 205CCCCN format.

14.2 Card 205CCC00 or 205CCCC0, Control Component Type

This card is required. One card must be entered for each of the generic control components when using the self-initialization option.

W1(A) Alphanumeric name. Enter a name descriptive of the component. This name will appear in the printed output along with the component number. A limit of 8 characters is allowed for most computers, e.g., workstations, CRAY, and IBM computers.

W2(A) Control component type. Enter one of the component names, SUM, MULT, DIV, DIFFRENI, DIFFREND, INTEGRAL, FUNCTION, STDFNCTN, DELAY, TRIPUNIT, TRIPDLAY, POWERI, POWERR, POWERX, PROP-INT, LAG, LEAD-LAG, CONSTANT, SHAFT, PUMPCTL, STEAMCTL, FEEDCTL, INVKIN, or the command, DELETE. If DELETE is entered, enter any alphanumeric word in Word 1 and zeros in the remaining words. No other cards are needed when deleting a component.

W3(R) Scaling factor. For a CONSTANT component, this quantity is the constant value. No additional words are entered on this card, and Cards 205CCC01 through 205CCC09 or 205CCCC1 through 205CCCC9 are not entered. For the PUMPCTL, STEAMCTL, or FEEDCTL components, this is the gain multiplier (G) for the output signal.

W4(R) Initial value.

W5(I) Initial value control flag. Zero (initialization control flag is off) means no initial condition calculation, and W4 is used as the initial condition; one (initialization control flag is on) means compute initial condition.

W6(I) Limiter control. Enter zero, or omit this and the following words if no limits on the control variable are to be imposed. Enter 1 if only a minimum limit is to be imposed, 2 if only a maximum limit is to be imposed, and enter 3 if both minimum and maximum limits are to be imposed.

W7(R) Minimum or maximum value. This word is the minimum or maximum value if only one limit is to be imposed or is the minimum value if both limits are to be imposed.

W8(R) Maximum value. This word is used if both limits are to be imposed.

14.3 Cards 205CCC01 through 205CCC99 or 205CCCC1 through 205CCCC9, Control Component Data

These cards are required. The format of these cards depends on the control component type. An equation is used to describe the processing by each component. The symbol Y represents the control variable defined by the component. The symbols A_j, j = 1, 2, ..., J, represent constants defined by the control component input data. The variables V_j, j = 1, 2, ..., J, represent any of the variables listed in the minor edit input description. Besides hydrodynamic component data, heat structure data, reactor kinetic data, etc., any of the control variables including the variable being defined may be specified. The symbol S is the scale factor (or G, the gain multiplier, for self-initialization control components) on Card 205CCC00 or 205CCCC0. The variables V_j use the code's internal units (SI). To use British units, the user must convert from SI to British using the scale factor S (or the gain multiplier G) and the constants A_j.

See Section 6 of Volume I for a detailed description of these models.

14.3.1 Sum-Difference Component

This component is indicated by SUM in Word 2 of Card 205CCC00 or 205CCCC0. The sum-difference component is defined by

$$Y = S(A_0 + A_1V_1 + A_2V_2 + ... + A_jV_j) \ .$$

W1(R) Constant A_0.

W2(R) Constant A_1.

W3(A) Alphanumeric name of variable request code for V_1.

W4(I) Numeric (parameter) part of the variable request code for V_1. At least four words that define a constant and one product term must be entered. Additional sets of three words corresponding to Words 2 through 4 can be entered for additional product terms, up to fifty product terms. One or more cards may be used as desired. Card numbers need not be strictly consecutive. The sign of A_j determines addition or subtraction of the product terms.

14.3.2 Multiplier Component

This component is indicated by MULT in Word 2 of Card 205CCC00 or 205CCCC0. The multiplier component is defined by

$$Y = SV_1V_2...V_j \ .$$

W1(A) Alphanumeric name of the variable request code for V_1.

W2(I) Numeric (parameter) part of the variable request code for V_1. At least two words must be entered. Additional pairs of words can be entered on this or additional cards to define additional factors, up to twenty pairs. Card numbers need not be strictly consecutive.

14.3.3 Divide Component

This component is indicated by DIV in Word 2 of Card 205CCC00 or 205CCCC0. The divide component is defined by

$$Y = \frac{S}{V_1} \quad \text{or} \quad Y = \frac{SV_2}{V_1} \ .$$

Specifying two words on the card indicates the first form, and specifying four words on the card indicates the second form. Execution will terminate if a divide by zero is attempted.

W1(A) Alphanumeric name of the variable request code for V_1.

W2(I) Numeric (parameter) part of the variable request code for V_1.

W3(A) Alphanumeric name of the variable request code for V_2.

W4(I) Numeric (parameter) part of the variable request code for V_2.

14.3.4 Differentiating Components

These components are indicated by DIFFRENI or DIFFREND in Word 2 of Card 205CCC00 or 205CCCC0. The differentiating component is defined by

$$Y = S\frac{dV_1}{dt} \quad .$$

This is evaluated by

$$Y = \frac{2S}{\Delta t}(V_1 - V_{10}) - Y_0 \qquad \text{(DIFFERENI)}$$

$$Y = S\frac{(V_1 - V_{10})}{\Delta t} \qquad \text{(DIFFREND)}$$

where Δt is the time step, and V_{10} and Y_0 are values at the beginning of the time step. The numerical approximations for the DIFFRENI and INTEGRAL components are exact inverses of each other. However, an exact initial value is required to use the DIFFRENI component, and erroneous results are obtained if an exact initial value is not furnished. The DIFFREND component uses a simple difference approximation that is less accurate and is not consistent with the integration approximation, but does not require an initial value. For these reasons, use of DIFFRENI is not recommended.

Since differentiation, especially numerical differentiation, can introduce noise into the calculation, it should be avoided if possible. When using control components to solve differential equations, the equations can be arranged such that INTEGRAL components can handle all indicated derivatives except possibly those involving noncontrol variables.

W1(A) Alphanumeric name of variable request code for V_1.

W2(I) Numeric (parameter) part of variable request code for V_1.

14.3.5 Integrating Component

This component is indicated by INTEGRAL in Word 2 of Card 205CCC00 or 205CCCC0. The integrating component is defined by

$$Y = S\int_0^t V_i dt$$

or, in Laplace notation,

$$Y(s) = \frac{SV_1(s)}{s} \quad .$$

This is evaluated by

$$Y = Y_0 + S \bullet (V_1 + V_{10})\frac{\Delta t}{2}$$

where Δ is the time step and Y_0 and V_{10} are values at the beginning of the time step.

W1(A) Alphanumeric name of the variable request code for V_1.

W2(I) Numeric (parameter) part of the variable request code for V_1.

14.3.6 Functional Component

This component is indicated by FUNCTION in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = S[FUNCTION (V_1)]$$

where FUNCTION is defined by a general table. This allows the use of any function that is conveniently defined by a table lookup and linear interpolation procedure. The function component can also be used to set limiting values.

W1(A) Alphanumeric name of the variable request code for V_1.

W2(I) Numeric (parameter) part of the variable request code for V_1.

W3(I) General table number of the function.

14.3.7 Standard Function Component

This component is indicated by STDFNCTN in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = S[FNCTN (V_1, V_2, ...)]$$

where FNCTN is ABS (absolute value), SQRT (square root), EXP (e raised to power), LOG (natural logarithm), SIN (sine), COS (cosine), TAN (tangent), ATAN (arc tangent), MIN (minimum value), or

MAX (maximum value). All function types except MIN and MAX must have only one argument; MIN and MAX function types must have at least two arguments and may have up to twenty arguments. If the control variable being defined also appears in the argument list of MIN or MAX, the old time value is used in the comparison.

W1(A) FNCTN.

W2(A) Alphanumeric name of the variable request code for V_1.

W3(I) Numeric (parameter) part of the variable request code for V_1.

14.3.8 Delay Component

This component is indicated by DELAY in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = SV_1 (t - t_d)$$

where t is time and t_d is the delay time.

W1(A) Alphanumeric name of the variable request code for V_1.

W2(I) Numeric (parameter) part of the variable request code for V_1.

W3(R) Delay time, t_d (s).

W4(I) Number of hold positions. This quantity, h, must be > 0 and $\leq$ 100. This quantity determines the length of the table used to store past values of the quantity V_1. The maximum number of time-function pairs that can be stored is h + 2. The delay table time increment, d_{TM}, is $d_{TM} = \frac{t_d}{h}$. The delayed function is obtained by linear interpolation for $V_1(t - t_d)$ using the stored past history. As the problem is advanced in time, new time values are added to the table. Once the table is filled, new values replace values that are older than the delay time. There are no restrictions on t_dT or d_{TM} relative to the time steps on Cards 201-299. When a change in advancement time is made at a restart, the time values in this table are changed to have time values as if the problem in the restart had run to the new advancement time.

14.3.9 Unit Trip Component

This component is indicated by TRIPUNIT in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = S \bullet U(\pm T_1)$$

where U is 0.0 if the trip, T_1, is false and is 1.0 if the trip is true. If the complement of T_1 is specified, U is 1.0 if the trip is false and 0.0 if the trip is true.

W1(I) Trip number. A minus sign may prefix the trip number to indicate that the complement of the trip is to be used.

14.3.10 Trip Delay Component

This component is indicated by TRIPDLAY in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = ST_{rptim}(T_1)$$

where T_{rptim} is the time the trip last turned true. If the trip is false, the value is -1.0; if the trip is true, the value is zero or a positive number.

W1(I) Trip number, T_1.

14.3.11 Integer Power Component

This component is indicated by POWERI in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = SV_1^I .$$

W1(A) Alphanumeric name of the variable request code for V_1.

W2(I) Numeric (parameter) part of the variable request code for V_1.

W3(I) I.

14.3.12 Real Power Component

This component is indicated by POWERR in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = SV_1^R .$$

W1(A) Alphanumeric name of the variable request code for V_1.

W2(I) Numeric (parameter) part of the variable request code for V_1.

W3(R) R.

14.3.13 Variable Power Component

This component is indicated by POWERX in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = SV_1^{V_2} \quad .$$

W1(A) Alphanumeric name of the variable request code for V_1.

W2(I) Numeric (parameter) part of the variable request code for V_1.

W3(A) Alphanumeric name of the variable request code for V_2.

W4(I) Numeric (parameter) part of the variable request code for V_2.

14.3.14 Proportional-Integral Component

This component is indicated by PROP-INT in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = S\left[A_1 V_1 + A_2 \int_0^t V_1 dt\right]$$

or in Laplace transform notation,

$$Y(s) = S\left[A_1 + \frac{A_2}{s}\right]V_1(s) \quad .$$

If the initialization control flag is one,

$$Y(t_0) = SA_1V_1(t_0) \quad .$$

If it is desired that the output quantity Y remain constant as long as the input quantity remains constant, V_1 must initially be zero regardless of the initialization control flag.

W1(R) A_1.

W2(R) A_2.

W3(A) Alphanumeric name of the variable request code for V_1.

W4(I) Numeric (parameter) part of the variable request code for V_1.

14.3.15 Lag Component

This component is indicated by LAG in Word 2 of Card 205CCC00 or 205CCCC0. This component is defined by

$$Y = \int_0^t \left(\frac{SV_1 - Y}{A_1}\right) dt$$

or, in Laplace transform notation,

$$Y(s) = \frac{S}{1 + A_1 s} V_1(s) \quad .$$

If the initialization control flag is on or off,

$$Y(t_0) = SV_1(t_0) \quad .$$

If the initialization control flag is set on or off, and if the initial values of Y and V_1 satisfy a specified relationship, Y remains constant as long as V_1 retains its initial value.

W1(R) Lag time, A_1 (s).

W2(A) Alphanumeric name of the variable request code for V_1.

W3(I) Numeric (parameter) part of the variable request code for V_1.

14.3.16 Lead-Lag Component

This component is indicated by LEAD-LAG in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = \frac{A_1 SV_1}{A_2} + \int_0^t \left(\frac{SV_1 - Y}{A_2}\right) dt$$

or, in Laplace transform notation,

$$Y(s) = S\frac{1 + A_1 s}{1 + A_2 s}V_1(s) \quad .$$

If the initialization control flag is on,

$$Y(t_0) = SV_1(t_0) \quad .$$

If the initialization control flag is on, and if the initial values of Y and V_1 satisfy a specified relationship, Y remains constant as long as V_1 retains its initial value.

W1(R) Lead time, A_1 (s).

W2(R) Lag time, A_1 (s).

W3(A) Alphanumeric name of the variable request code for V_1.

W4(I) Numeric (parameter) part of the variable request code for V_1.

14.3.17 Constant Component

This component is indicated by CONSTANT in Word 2 of Card 205CCC00 or 205CCCC0. Cards 205CCC01 through 205CCC99 or 205CCCC1 through 205CCCC9 are not entered. The quantity in Word 3 of Card 205CCC00 or 205CCCC0 is the constant value used for this component.

14.3.18 Shaft Component

This component is indicated by SHAFT in Word 2 of Card 205CCC00 or 205CCCC0. A GENERATR component may optionally be associated with a SHAFT component. The SHAFT component advances the rotational velocity equation

$$\sum_i I_i \frac{d\omega}{dt} = \sum_i \tau_i - \sum_i f_i \omega + \tau_c$$

where I_i is the moment of inertia of component i, ω is rotational velocity, τ_i is torque of component i, f_i is the friction factor of component i, and τ_c is an optional torque from a control component. The summations include the shaft as well as the pump, turbine, and generator components that are connected to the shaft.

The SHAFT control component differs somewhat from other control components. The scale factor on Card 205CCC00 or 205CCCC0 must be 1.0. The initial value and optional minimum and maximum values have units (rad/s, rev/min), and British-SI units conversion are applied to these quantities. The output of the SHAFT in minor and major edits is in the requested units. Card number ranges are restricted so that both data to complete the SHAFT component description and optional data to describe a generator can be entered. Units conversion is applied to the following cards.

14.3.18.1 Cards 205CCC01 through 205CCC05 or 205CCCC1 through 205CCCC5, Shaft Description.

W1(I) Torque control variable number. If zero, there is no contribution to torque from the control system. If nonzero, the control variable with this number is assumed to be a torque and is added to the torques from the other components attached to the shaft. The torque must be in SI units.

W2(R) Shaft moment of inertia, I_i ($kg \bullet m^2$, $lb_m \bullet ft^2$).

W3(R) Friction factor for the shaft, f_i ($N \bullet m \bullet s$, $lb_f \bullet ft \bullet s$).

W4(A) Type of attached component. Enter either TURBINE, PUMP, or GENERATR.

W5(I) Component number. This is the hydrodynamic component number for a TURBINE or PUMP, or the control variable number for this SHAFT component if GENERATR.

Additional two-word pairs may be entered to attach additional components to the shaft, up to a total of fifty components. Only one generator, the one which is defined as part of this SHAFT component, may be attached.

14.3.18.2 Card 205CCC06 or 205CCCC6, Generator Description. Each SHAFT component may optionally define an associated GENERATR component.

W1(R) Initial rotational velocity (rad/s, rev/min).

W2(R) Synchronous rotational velocity (rad/s, rev/min).

W3(R) Moment of inertia, I_i ($kg \bullet m^2$, $lb_m \bullet ft^2$).

W4(R) Friction factor, f_i ($N \bullet m \bullet s$, $lb_f \bullet ft \bullet s$).

W5(I) Generator trip number. When the trip is false, the generator is connected to an electrical distribution system and rotational velocity is forced to the synchronous speed. When the trip is true, the generator is not connected to an electrical system and the generator and shaft rotational velocity is computed from the rotational velocity equation.

W6(I) Generator disconnect trip number. If zero, the generator is always connected to the shaft. If nonzero, the generator is connected to the shaft when the trip is false and disconnected when the trip is true.

14.3.19 PUMPCTL Component

This component is indicated by PUMPCTL in Word 2 of Card 205CCC00 or Card 205CCCC0. This component is specified when using the self-initialization option to control loop flow, but it is not limited to that use. For each PUMPCTL component enter

W1(A) Alphanumeric name of setpoint variable.

W2(I) Numeric (parameter) part of setpoint variable.

W3(A) Alphanumeric name of sensed variable.

W4(I) Numeric (parameter) part of sensed variable.

W5(R) Scale factor(s) applied to sensed and setpoint values, S_i. Must be nonzero.

W6(R) Integral name time constant, T_2 (s).

W7(R) Proportional part time constant, T_1 (s).

Standard use of PUMPCTL controller require the following interpretation of the input data. W1 and W2 contain CNTRLVAR and CCC (or CCCC), respectively, where CCC (or CCCC) is a CONSTANT type control element containing the desired (setpoint) flow rate. W3 is MFLOWJ, and W4 is the junction number at which the flow is to be sensed and compared to the setpoint. W5 is the S_i value used to divide the difference between the desired (setpoint) and sensed flow rate to produce the error signal E_1. E_1 must be initially zero if it is intended to have the controller output remain constant as long as the input quantities remain constant. W6 and W7 are the T_2 and T_1 values, respectively. All variables having units must be in SI units.

14.3.20 STEAMCTL Component

This component is indicated by STEAMCTL in Word 2 of Card 205CCC00 or 205CCCC0. This component is specified when using the self-initialization option to control steam flow from one or more steam generators, but it is not limited to that use. For each STEAMCTL component enter

W1(A) Alphanumeric name of setpoint variable.

W2(I) Numeric (parameter) part of setpoint variable.

W3(A) Alphanumeric name of sensed variable.

W4(I) Numeric (parameter) part of sensed variable.

W5(R) Scale factor(s) applied to sensed and setpoint values, S_j. Must be nonzero.

W6(R) Integral name time constant, T_4 (s).

W7(R) Proportional part time constant, T_3 (s).

Standard use of the STEAMCTL controller requires the following interpretation of the input data. W1 and W2 would contain CNTRLVAR and CCC (or CCCC), respectively, where CCC (or CCCC) is a CONSTANT type control element. This constant would be the desired (setpoint) cold leg temperature (for suboptions A and B) or secondary pressure (suboptions C and D). W3 would be TEMPF (for suboptions A and B) or P (for suboptions C and D), and W4 would be the volume number where the temperature (suboptions A and B) or pressure (suboptions C and D) is sensed. W5 is the S_j value used to divide the difference between the desired (setpoint) and sensed temperature (suboptions A and B) or pressure (suboptions C and D) to produce the error signal E_2. E_2 must be initially zero if it is intended to have the controller output remain constant as long as the input quantities remain constant. W6 and W7 are the T_4 and T_3 values respectively. All variables having units must be in SI units.

14.3.21 FEEDCTL Component

This component is indicated by FEEDCTL in Word 2 of Card 205CCC00 or 205CCCC0. This component is specified when using the self-initialization option to control feedwater flow to a steam generator, but it is not limited to that use. For each FEEDCTL component enter

W1(A) Alphanumeric name of first setpoint variable.

W2(I) Numeric (parameter) part of first setpoint variable.

W3(A) Alphanumeric name of sensed variable to be compared with first setpoint.

W4(I) Numeric (parameter) part of sensed variable to be compared with first setpoint.

W5(R) Scale factor applied to sensed and setpoint values (first setpoint), S_k. Must be nonzero.

W6(A) Alphanumeric name of second setpoint variable.

W7(I) Numeric (parameter) part of second setpoint variable.

W8(A) Alphanumeric name of sensed variable to be compared with second setpoint.

W9(I) Numeric (parameter) part of sensed variable to be compared with second setpoint.

W10(R) Scale factor applied to sensed and setpoint values (second setpoint), S_m. Must be nonzero.

W11(R) Integral name time constant, T_6 (s).

W12(R) Proportional part time constant, T_5 (s).

Standard use of the FEEDCTL controller requires the following interpretation of the input data. W1 and W2 contain CNTRLVAR and CCC (or CCCC), respectively, where CCC (or CCCC) is a CONSTANT type control element. This constant would be the desired (setpoint) steam generator secondary side water level. The latter may be expressed alternatively as a desired secondary coolant mass or as a differential pressure measured between two locations in the steam generator downcomer. W3 and W4 would contain CNTRLVAR and CCC (or CCCC), respectively, where CCC (or CCCC) is the number of the control component that describes the summing algorithm to compute the sensed variable (e.g., collapsed water level may be computed by summing the product of VOIDF and volume length over the control volumes in the riser section). W5 is the S_k value used to divide the difference between the desired (setpoint) and sensed water level to produce the first portion of the error signal E_3. W6 is MFLOWJ, and W7 is the junction number of the steam exit junction from the steam generator. W8 is MFLOWJ, and W9 is the junction number of the feedwater inlet junction. W10 is the S_m value used to divide the difference between the sensed steam flow and sensed feedwater flow to produce the second portion of the error signal E_3. E_3 must be initially zero if it is intended to have the controller output remain constant as long as the input quantities remain constant. W11 and W12 are the T_6 and T_5 values, respectively. All variables having units must be in SI units.

14.3.22 Inverse Kinetics Component

This component is indicated by INVKIN in Word 2 of Card 205CCC00 or Card 205CCCC0. The component is defined by

$$Y = S\left(\frac{\frac{\Lambda}{\beta}\frac{dV_1}{dt} + \sum_{i=1}^{N_d} D_i(t_o + \Delta t)}{V_1}\right)$$

where

$$D_i(t_o + \Delta t) = e^{-\lambda_i \Delta t} D(t_o + \Delta t) + \frac{\beta_i}{\beta\lambda_i}(1 - e^{-\lambda_i \Delta t})\frac{dV_1}{dt}$$

where Δt is the time step size and t_o is the time at the beginning of the time step.

W1(A) Alphanumeric name of the variable request code for V_1.

W2(I) Integer name of the variable request code for V_1.

The following 14 words are optional. If not supplied, typical values are assigned. If any entry is input, all 14 items are required.

W3-W8(R) Delayed neutron precursor yield ratios, f_i (= β_i/β). Six values are required. The values must sum to one within a relative error of 1.0×10^{-6}.

W9-W14(R) Delayed neutron decay constant, λ_i (s^{-1}). Six values are required.

W15(R) Effective delayed neutron fraction, β. This quantity must be greater than zero. The default value is 0.0065, which is the value for ^{235}U.

W16(R) Prompt neutron generation time, Λ (s). This quantity must be greater than zero. The default value is 2.4×10^{-4} s, which is the value for light water.

15 Cards 22000000-22099999, Radionuclide Transport Input Data

These cards are required if the transport of radioactive species in the coolant systems is desired. These cards are used only in NEW or RESTART type problems. If no radionuclide transport data is present in a restart problem, the data will be added; if radionuclide transport data are already present, the data are deleted and replaced by the new data. A complete set of radionuclide transport data must always be entered. Initial conditions are computed in the same manner for new problems or restart problems with data replacement.

15.1 Card 22000000, Number of Radionuclide Species

This card is required if the transport of radionuclide species is desired.

W1(A) The number of radionuclide species. The maximum number of species must be less than or equal to 999.

15.2 Card 22NNN00, Basic Data for Radionuclide Specie.

These cards are required. The card contains the basic data for radionuclide specie NNN. The NNN portion of the card number has no significance other than to specify the order in which the input data for the radionuclide transport model are processed. The radionuclide species are specified for plotting and minor edits by their alphanumeric identifier (i.e., the first word on these cards) instead of by their sequence number.

W1(A) Alphanumeric identifier for specie. The identifier for each specie is limited to five characters. The character string N16 is a reserved identifier for the N^{16} radionuclide. The identifier may be entered in upper case, mixed case, or lower case. This datum is required.

W2(I) Phase flag. This flag specifies the fluid phase with which the radionuclide specie is transported. A value of zero means that the specie is transported by the liquid phase and a value of one means that the specie is transported by the vapor/gas phase. This datum is required.

W3(R) Radionuclide decay constant (sec^{-1}). This datum is required.

W4(R) Energy released by radionuclide decay (Mev). This datum is required.

W5(R) Molecular weight of specie (kg/kg-mole). This datum is required.

W6(A) Alphanumeric identifier for parent specie. This specie may be created by the radioactive decay of a parent specie or by neutron absorption in the parent specie. If a parent specie is specified for this specie, the data for the parent specie must be entered before the data for this specie (i.e., the value of NNN for the parent specie must be less that the value of NNN for this specie). This datum is optional and may be omitted or the value "none" may be entered if the specie has no parent (the parent specie for N16 must be entered as "none" because the parent for N^{16} is O^{16} that is contained in the H_2O coolant and is not any of the other radionuclide species). The identifier is limited to 5 characters. A value must be entered for this datum if the Words 7 through 9 are entered on this card.

W7(I) Radionuclide production flag. This flag is used for N16 or any other radionuclide that can be produced by neutron absorption in materials in the coolant. A value of zero means no production by neutron absorption in the parent specie and one means that this specie can be created by neutron absorption in the parent material. This value may only be non-zero if the nodal neutron kinetics has been activated by the user.

W8(R) Weight factor in specie production computation. A typical value would represent the ratio of the flux-volume integral in the fluid portion of a fuel cell to the flux-volume integral over the complete fuel cell. The value must be greater than or equal to zero and less than or equal to one. This value is optional and the default value is zero.

W9(R)-... Production cross sections for the parent nuclide (m^2). Data should be entered for the number of groups specified for the nodal kinetics model. These data are optional and have a default value of zero. The recommended values for N16 are a value of 20.2e-06 for neutron energy group 1 (the highest neutron energy group) and 0.0 for all the other neutron energy groups.

15.3 Cards 220NNN01-220NNN99, Radionuclide Transport Source Data

These cards are required for all species except for N16 and those species that are created by neutron absorption in their parent specie. The production computation (specified in Word 7 on Card 22NNN00 for this specie) is only available when the nodal neutron kinetics model has been activated. Production computations for N16 and any other specie that can be created by neutron absorption must be accomplished through control variables and sources if the point kinetics model has been selected by the user. Any number of sources (or sinks) may be specified for a specie and pairs of data items are entered for each source.

W1(I) Volume identifier for source. The volume identifier has the same format as for plot variables and minor edits (e.g., CCCNN0000 for volume NN in component CCC).

W2(I) Identifier of control variable or general table from which to compute the source (kg/s). The value must be greater than or equal to one and less than or equal to 20000. If the value is greater than 10000, the value is the identifier of a control variable whose identifier is the value minus 10000. If the value is less than 1000, the value is the identifier of a general table. A positive value from the control variable or general table means a source of the specie and a negative value means a sink for the specie.

16 Cards 1001 through 1999, Strip Request Data

These cards are required only in STRIP-type problems. One or more cards are entered, each card containing one variable request. Card numbers need not be consecutive. Variables are ordered on the STRIPF file in the order of increasing card numbers. If an incorrect variable request code is entered, the value will be 0.0. It is not flagged as an input error, since at some later time in the transient, a renodalization may result in the variable request code becoming correct.

W1(A) Alphanumeric name of the variable request code.

W2(I) Numeric (parameter) part of the variable request code.

17 Cards 1001 through 1999, Compare Dump Files Control Data

These cards are required only in CMPCOMS problems. One or more cards are entered, each card containing one request to compare dump blocks on the files specified with the -A and -B options on the command line. Card numbers need not be consecutive.

W1(I) Dump file number from file specified on -A command line option.

W2(I) Dump file number from file specified on -B command line option.

The values in Words 1 and 2 on a succeeding card must be greater than the values on the preceding card. The values in Words 1 and 2 are the advancement number when the dump block was written. This information is written as a line in the printed output of the run writing the dump file. The form of the line is, “---Dmpcom no. nnn written, block no. mmm on unit u---,” where nnn is the advancement count number, mmm is the count of the number of blocks written, and u is A or B indicating the file specified by the -A or -B option.

18 RELAP5-3D©-Based Code Operating Procedures

When operating on Unix systems, the RELAP5-3D©-based program can interpret a Unix-style command line. The command line below is written with all of the allowed options (prefixed by a minus sign), and each option is followed by its default value.

```
relap5.x -f ftb1 -i indta -o outdta -p plotfl -r rstplt -s stripf -j jbinfo \

-n null -c cdffile -a coupfl -X -C 0 -A dumpfil1 -B dumpfil2 -R rpdacc

-w tpfh2o -d tpfd2o -h tpfh2 -l tpfli -k tpfk -b tpfhe -e tpfn2 -m tpfna \

-q tpfnak -t tpflipb -u tpfnh3 -W tpfh2on -g tpfglyc -H tpfblood \

-L tpfbipb -S tpfh2o95 -G tpfco2 -F r5-r5f
```

If an option and its parameter are not entered, the default is used. With the exception of the X option, an option character must always be followed with a file name, and an option may not be repeated. The f option specifies a scratch word addressable file used only on CRAY versions. This file is a word addressable file, and the I/O is done by CRAY library subroutines that have successfully resisted external open and close statements. This file is small and can fit in most directories. This file should be removed after execution, but no error occurs in subsequent calculations if it is not removed. The file indta contains input data, outdta contains printed output, plotfl contains plotter information, rstplt is the restart-plot file, and stripf is the strip file. The files dumpfil1 and dumpfil2 are files used to dump common and dynamic blocks for debugging purposes. The files beginning with tpf (e.g., tpfh2o) are thermodynamic property files where the characters following the tpf are chemical names of the material. The RELAP5-3D© code uses only the light and heavy water (h2o and d2o) materials, the 1984 light water (h2on) material, and the 1995 light water (h2o95) material. The other materials are used when the ATHENA option is use. The light water (h2o) material file tpfh2o must always be available even if h2o is not the working fluid for any of the systems. This is because h2o is used for volumes with incorrect initial conditions so as to complete the input processing. The file jbinfo is an optional file created by the user who wishes to place some additional information on his output file (such as a listing of the control cards used to run the job). The indta file must be available and the outdta file must not exist, or else a diagnostic message followed by immediate termination will follow. The rstplt file must not exist for a NEW problem and must exist for other types problems. The dumpfil1 and dumpfil2 files must not exist for the run that creates them and must exist for the CMPCOMS run. Most of the other options are for operation with the Nuclear Plant Analyzer (NPA). The r5-r5f file is the R5FORCE file, which contains output that is needed by R5FORCE.

The command line capability eliminates the need to have all files needed for execution in the same directory or to copy/rename files to match the default names. For example, the command:

```
relap5.x -i myprob.i -o /usr/tmp/rjw/myprob.o \
```

```
-r /usr/tmp/rjw/myprob.r -w /u2/rjw/relap5/tpfh2o
```

takes the executable file and input file from the current directory, uses a temporary disk for the output and restart-plot files, and uses a water property file from a different directory.

For operating systems other than Unix, the default file names must be used.

Appendix B
Example of a Diagnostic Edit

Appendix B
Example of a Diagnostic Edit

This appendix contains an example (**Figure B-1**) of a diagnostic edit for one time step using the semi-implicit scheme for the case when HELP = 3. As can be seen from the figure, this edit can be quite lengthy. As Section 2 of Volume I of this manual indicates, there are many subroutines called from the main hydrodynamic subroutine HYDRO and the main heat transfer/conduction subroutine HTADV. The diagnostic edit prints out information for most of the subroutines called by these two subroutines In addition, the particular ones printed will vary, depending on whether the time step is repeated, if bad donoring occurs, if the choking model is turned on, whether heat structures are present or not, whether the heat time advancement is different from the hydrodynamic time advancement, etc. For the example presented here, the time step is not a repeated time step, a heat transfer calculation occurs, and a choking diagnostic edit occurs. In order to save space in the appendix, only the first 3 heat structures, the first 3 volumes, and the first 2 junctions are shown.

Each subroutine section of the edit (except heat transfer) begins with a line of pound signs (###...). The next line lists the name of the subroutine, the label DIAGNOSTIC PRINTOUT, the simulated time (TIMEHY), the time step size (DT), the total attempted advancements (NCOUNT), and the value of the variables HELP, SUCCES, and FAIL. HELP is explained in Section 8 of this manual. SUCCES is a code variable that indicates if a time step is successful (SUCCES = 0 means successful, SUCCES = 1 or 2 means unsuccessful). FAIL is a code variable that is normally false (F) until the code fails, and then it becomes true (T). The printing of most of these blocks can be controlled by the user through input cards 4 or 5 (See Section 2.2 of Appendix A of this volume) to reduce the size of the diagnostic edits.

The order of the subroutines in the diagnostic edit printed in **Figure B-1** is as follows:

Heat transfer subroutines (HTRC1 plus appropriate correlation subroutines.)

VOLVEL

PHANTV

PHANTJ

FWDRAG

VEXPLT

JCHOKE

JPROP

PRESEQ

SYSSOL

JPROP

VFINL

EQFINL

STATE

MASS ERR

JPROP

VLVELA

MS ERR T

The particular quantities printed out in each subroutine will not be presented here. Most of the tables are grouped by volumes and junctions, and they usually begin with either the volume number (VOLNO) or the junction number (JUNNO). The definition of many of these volume and junction terms are listed in the comment common blocks VOLDATC and JUNDATC in ATHENA. A copy of these blocks is contained in **Figure B-2** and **Figure B-3** as an aid to understanding this diagnostic edit. Many of the other quantities printed out are calculated only within that particular subroutine, and they are printed because it was felt they were important in debugging that subroutine.

```
o  htrc1 initial :   id =     30001   volno =   3010000   irwt =  0
     tw            htdiam        htsa        p             tsatt         satt          voidg         g             v
     5.016510E+02  7.620002E-02  4.902718E-02  6.405464E+05  4.345595E+02  4.345595E+02  9.451944E-01  2.404556E+01  9.339683E-04
     tempf         tempg
     4.356360E+02  4.341691E+02
 In chfcal
  CHF debug printout, ncount, volno, time         509    3010000 5.00000E-01
  Passed in and calculated quantities, both aqueous and nonaqueous
  p, pm, g, ga, gabs, gab, rf/rg, rfa, rfna
  6.40546E+05 6.40546E-01 2.40456E+01 2.40456E+01 2.40456E+01 2.40456E+01 0.00000E+00 0.00000E+00 0.00000E+00
  rga, rgna, hfga, hfgp, siga, sigma, x, diamv, aqua
  0.00000E+00 0.00000E+00 2.07619E+06 2.07619E+06 4.62893E-02 4.62893E-02 2.27550E-01 7.62000E-02 1.00000E+00
          p,g,x,ip,ig,ix= 0.640546E+06 0.240456E+02 0.227550E+00    6    3   13
               k1,k2,k3,k4,k5,k6,k7,k8=  0.79000      1.0000      1.0000      1.2009      1.0000     0.00000E+00  1.0000      1.0000
    chf =  0.000000E+00     chfmul=  0.000    hfgp,rhf,rhg,sigma,aqua =  0.207619E+07  904.809      3.37673     0.462893E-01  1.00000
     prednb - thconf        viscf         csubpf        sigma         tw-tsatt      rhof          rhog          hfgp
              6.823210E-01  1.674918E-04  4.344334E+03  4.628926E-02  6.709156E+01  9.048091E+02  3.376729E+00  2.076186E+06
     dittus - tf            thcons        viscs         cps
              4.356360E+02  6.823210E-01  1.674918E-04  4.344334E+03
              htcoef        qfluxo        mode     hlam          hnat          hturb
              7.595107E+02  5.013909E+04     2  3.904093E+01  7.595107E+02  2.920891E+02
    prednb    hmac          f             hmic          sf            htcoef        qfluxo        chf
              5.414682E+03  7.129171E+00  8.293794E+04  3.813658E-01  8.835262E+04  5.921886E+06  0.000000E+00
     pstdnb - thcons        viscs         csubpg        rhof          rhog          sigma
              3.372731E-02  1.575588E-05  2.414047E+03  9.048091E+02  3.376729E+00  4.628926E-02
     dittus - tf            thcons        viscs         cps
              4.345595E+02  3.372731E-02  1.575588E-05  2.414047E+03
              htcoef        qfluxo        mode     hlam          hnat          hturb
              3.750358E+01  2.516174E+03     9  1.929804E+00  9.340970E+00  3.750358E+01
     pstdnb -htbf          htbg          qtfbf         qtfbg         hfb           hv            qfbf          qfbg
              0.000000E+00  3.580729E+01  0.000000E+00  2.402367E+03  5.111356E+00  3.750358E+01  3.429289E+02  2.516174E+03
              htcoef        qfluxo          qfb           qtb
              4.261493E+01  2.859102E+03  2.859102E+03  2.402367E+03
   suboil final output :
     gamw        gammul           qffo        peclet         numod         enmin        encrit       sathfp
  8.670467E-03  2.528357E-05  3.429289E+02  1.166607E+04  3.829750E+01  6.817137E+05  6.813481E+05  6.817137E+05
   htrc1 final output :
     mode     chf           htcoef        htcf          htcg          qfluxo        qffo          qfgo
        8     0.000000E+00  4.261493E+01  5.111356E+00  3.750358E+01  2.859102E+03  3.429289E+02  2.516174E+03
              gamw          fstrt          quala          quale         dtsat         sathfp
              8.670467E-03  1.000000E+00  0.000000E+00  2.275499E-01  6.709156E+01  6.817137E+05
o  htrc1 initial :   id =     30002   volno =   3020000   irwt =  0
     tw            htdiam        htsa        p             tsatt         satt          voidg         g             v
     5.011370E+02  7.620002E-02  4.902718E-02  6.404966E+05  4.345564E+02  4.345564E+02  9.317909E-01  7.940285E+01  9.339683E-04
     tempf         tempg
     4.354654E+02  4.342100E+02
 In chfcal
  CHF debug printout, ncount, volno, time         509    3020000 5.00000E-01
  Passed in and calculated quantities, both aqueous and nonaqueous
  p, pm, g, ga, gabs, gab, rf/rg, rfa, rfna
  6.40497E+05 6.40497E-01 7.94029E+01 7.94029E+01 7.94029E+01 7.94029E+01 0.00000E+00 0.00000E+00 0.00000E+00
  rga, rgna, hfga, hfgp, siga, sigma, x, diamv, aqua
  0.00000E+00 0.00000E+00 2.07620E+06 2.07620E+06 4.62899E-02 4.62899E-02 2.18124E-01 7.62000E-02 1.00000E+00
          p,g,x,ip,ig,ix= 0.640497E+06 0.794029E+02 0.218124E+00    6    4   13
               k1,k2,k3,k4,k5,k6,k7,k8=  0.79000      1.0000      1.0000      1.2006      1.0000     0.00000E+00  1.0000      1.0000
```

Figure B-1 Diagnostic edit from Edwards pipe problem with extras.

```
  chf =  0.000000E+00     chfmul=  0.000    hfgp,rhf,rng,sigma,aqua =  0.207620E+07  904.978      3.37604     0.462899E-01  1.00000
   prednb - thconf        viscf         csubpf        sigma         tw-tsatt      rhof          rhog          hfgp
            6.823593E-01  1.674952E-04  4.344325E+03  4.628992E-02  6.658064E+01  9.049778E+02  3.376043E+00  2.076196E+06
   dittus - tf            thcons        viscs         cps
            4.354654E+02  6.823593E-01  1.674952E-04  4.344325E+03
            htcoef        qfluxo        mode     hlam          hnat          hturb
            7.685994E+02  5.047516E+04     2  3.904312E+01  7.586511E+02  7.685994E+02
  prednb    hmac          f             hmic          sf            htcoef        qfluxo        chf
            5.257292E+03  6.840094E+00  3.042331E+04  1.414360E-01  3.568060E+04  2.370858E+06  0.000000E+00
   pstdnb - thcons        viscs         csubpg        rhof          rhog          sigma
            3.370634E-02  1.574475E-05  2.414020E+03  9.049778E+02  3.376043E+00  4.628992E-02
   dittus - tf            thcons        viscs         cps
            4.345564E+02  3.370634E-02  1.574475E-05  2.414020E+03
            htcoef        qfluxo        mode     hlam          hnat          hturb
            9.367075E+01  6.236659E+03     9  1.928604E+00  9.322819E+00  9.367075E+01
   pstdnb -htbf          htbg          qtfbf         qtfbg         hfb           hv            qfbf          qfbg
            0.000000E+00  8.553882E+01  0.000000E+00  5.695230E+03  7.895455E+00  9.367075E+01  5.256845E+02  6.236659E+03
            htcoef        qfluxo          qfb           qtb
            1.015662E+02  6.762343E+03  6.762343E+03  5.695230E+03
 suboil final output :
   gamw        gammul           qffo        peclet         numod         enmin        encrit       sathfp
 1.329112E-02  2.528345E-05  5.256845E+02  3.852126E+04  5.870393E+01  6.817004E+05  6.811399E+05  6.817004E+05
 htrc1 final output :
   mode     chf           htcoef        htcf          htcg          qfluxo        qffo          qfgo
      8     0.000000E+00  1.015662E+02  7.895455E+00  9.367075E+01  6.762343E+03  5.256845E+02  6.236659E+03
            gamw          fstrt          quala          quale          dtsat          sathfp
            1.329112E-02  1.000000E+00  0.000000E+00  2.181238E-01  6.658064E+01  6.817004E+05
o  htrc1 initial :   id =     30003   volno =    3030000   irwt =  0
   tw            htdiam        htsa          p             tsatt         satt          voidg         g             v
   4.859351E+02  7.620002E-02  4.902718E-02  6.403597E+05  4.345479E+02  4.345479E+02  9.312849E-01  1.414440E+02  9.339683E-04
   tempf         tempg
   4.351487E+02  4.342624E+02
 In chfcal
 CHF debug printout, ncount, volno, time         509    3030000 5.00000E-01
 Passed in and calculated quantities, both aqueous and nonaqueous
 p, pm, g, ga, gabs, gab, rf/rg, rfa, rfna
 6.40360E+05 6.40360E-01 1.41444E+02 1.41444E+02 1.41444E+02 1.41444E+02 0.00000E+00 0.00000E+00 0.00000E+00
 rga, rgna, hfga, hfgp, siga, sigma, x, diamv, aqua
 0.00000E+00 0.00000E+00 2.07622E+06 2.07622E+06 4.62917E-02 4.62917E-02 2.12822E-01 7.62000E-02 1.00000E+00
         p,g,x,ip,ig,ix= 0.640360E+06 0.141444E+03 0.212822E+00    6    5   13
              k1,k2,k3,k4,k5,k6,k7,k8=  0.79000      1.0000      1.0000      1.2004      1.0000     0.18943      1.0000      1.0000
  chf =   404743.         chfmul=  0.180    hfgp,rhf,rhg,sigma,aqua =  0.207622E+07  905.291      3.37476     0.462917E-01  1.00000
   prednb - thconf        viscf         csubpf        sigma         tw-tsatt      rhof          rhog          hfgp
            6.824303E-01  1.675045E-04  4.344300E+03  4.629173E-02  5.138721E+01  9.052910E+02  3.374755E+00  2.076224E+06
   dittus - tf            thcons        viscs         cps
            4.351487E+02  6.824303E-01  1.675045E-04  4.344300E+03
            htcoef        qfluxo        mode     hlam          hnat          hturb
            1.226662E+03  6.229773E+04     2  3.904718E+01  7.116532E+02  1.226662E+03
  prednb    hmac          f             hmic          sf            htcoef        qfluxo        chf
            8.224450E+03  6.704742E+00  1.422551E+04  9.506101E-02  2.244996E+04  1.148699E+06  4.047429E+05
   pstdnb - thcons        viscs         csubpg        rhof          rhog          sigma
            3.311139E-02  1.541671E-05  2.413948E+03  9.052910E+02  3.374755E+00  4.629173E-02
   dittus - tf            thcons        viscs         cps
            4.345479E+02  3.311139E-02  1.541671E-05  2.413948E+03
            htcoef        qfluxo        mode     hlam          hnat          hturb
```

Figure B-1 Diagnostic edit from Edwards pipe problem with extras. (Continued)

```
             1.454092E+02  7.472172E+03     9  1.894562E+00  8.752997E+00  1.454092E+02
    pstdnb -htbf          htbg          qtfbf         qtfbg         hfb           hv            qfbf          qfbg
             1.583266E+03  1.161797E+02  8.135961E+04  5.970149E+03  8.460500E+00  1.454092E+02  4.347615E+02  7.472172E+03
             htcoef        qfluxo         qfb           qtb
             1.699446E+03  8.732976E+04  7.906933E+03  8.732976E+04
  suboil final output :
    gamw        gammul          qffo        peclet         numod         enmin        encrit       sathfp
 2.057025E+00  2.528312E-05  8.135961E+04  6.861217E+04  9.084597E+03  6.816637E+05  5.949248E+05  6.816637E+05
  htrc1 final output :
    mode     chf           htcoef        htcf          htcg          qfluxo        qffo          qfgo
       6     4.047429E+05  1.699446E+03  1.583266E+03  1.161797E+02  8.732976E+04  8.135961E+04  5.970149E+03
             gamw          fstrt          quala          quale         dtsat          sathfp
             2.057025E+00  8.105669E-01  0.000000E+00  2.128222E-01  5.138721E+01  6.816637E+05
0####################################################################################################################################
    volvel Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =      509, help =  3, lsuces =  0, fail = F
0Volume inlet and outlet terms
 ===================================================================================================================================
       volno(i)             invcnt(l)
       avol(i)     iiflag   loop jx    junno(jx)  ivf ajun(jx)     voidfj(jx)   rhofj(jx)    velfjo*ivf   arat(jx)     cvelf(ivr)
                                                      athrot(jx)   voidgj(jx)   rhogj(jx)    velgjo*ivf   arat(jx+1)   cvelg(ivr)
 ===================================================================================================================================
       003010000            1
       4.56037E-03
+                  outlet   1          003010000  1   4.56037E-03  5.48056E-02   904.81      0.74716       1.0000      0.00000E+00
                                                       1.0000      0.94519       3.3767       3.4585       1.0000      0.00000E+00
       003020000            2
       4.56037E-03
+                  inlet    1          003010000  1   4.56037E-03  5.48056E-02   904.81      0.74716       1.0000      0.00000E+00
                                                       1.0000      0.94519       3.3767       3.4585       1.0000      0.00000E+00
                   outlet   2          003020000  1   4.56037E-03  6.82091E-02   904.98       1.4113       1.0000      0.00000E+00
                                                       1.0000      0.93179       3.3760       7.5009       1.0000      0.00000E+00
       003030000            2
       4.56037E-03
+                  inlet    1          003020000  1   4.56037E-03  6.82091E-02   904.98       1.4113       1.0000      0.00000E+00
                                                       1.0000      0.93179       3.3760       7.5009       1.0000      0.00000E+00
                   outlet   2          003030000  1   4.56037E-03  6.87151E-02   905.29       2.1800       1.0000      0.00000E+00
                                                       1.0000      0.93128       3.3748       11.633       1.0000      0.00000E+00
0Volume average terms
 ===================================================================================================================================
     volno(i)   sumvfx(ix)   difvfx(ix)   vvfx(ix)     vvfx(ix+1)   vfa(ix)      vfa(ix+1)    vrhof(ix)    vrhof(ix+1)  areav(ix)
                sumvgx(ix)   difvgx(ix)   vvgx(ix)     vvgx(ix+1)   vga(ix)      vga(ix+1)    vrhog(ix)    vrhog(ix+1)  areav(ix+1)
 ===================================================================================================================================
     003010000  0.74716     -0.55825     0.00000E+00  0.74716      0.00000E+00  0.16897      0.00000E+00  0.22614      0.00000E+00
                 3.4585      -11.961     0.00000E+00   3.4585      0.00000E+00  5.03391E-02  0.00000E+00  1.45552E-02  4.56037E-03
     003020000   1.1155     -0.41083     0.74716       1.4113      0.16897      0.39729      0.22614      0.28150      4.56037E-03
                 5.4651      -10.966      3.4585       7.5009      5.03391E-02  0.10761      1.45552E-02  1.43459E-02  4.56037E-03
     003030000   1.7971     -0.69333      1.4113       2.1800      0.39729      0.61843      0.28150      0.28369      4.56037E-03
                 9.5662      -19.757      7.5009       11.633      0.10761      0.16674      1.43459E-02  1.43326E-02  4.56037E-03
0####################################################################################################################################
    phantv Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =      509, help =  3, lsuces =  0, fail = F
0Volume mass transfer terms
 ===================================================================================================================================
 i     volno(i)   hif(i)       hifo(i)      hifc         hifc1        dtsf         dtsfm        dtsfsp       dtsfsb       xliqh
       vctrl(i)   hig(i)       higo(i)      higc         higc1        dtsg         higsub       dtsgms       dtsgm        xvaph
       nmap       fluxm        avelf        avelfg       rhocpf       hfg          term         term1        rvcrit(ix)   scrach
```

Figure B-1 Diagnostic edit from Edwards pipe problem with extras. (Continued)

```
 =====================================================================================================================================
    1 003010000  6.31082E+07  6.33475E+07  4.91436E+07   1.0000      -1.0766       328.10       1.0000      0.00000E+00  6.86391E+05
              0  8.86346E+06  8.90658E+06  6.43145E+06   1.0000       0.39032      4.38413E+05  0.00000E+00   1.0000      2.75790E+06
              2   48.089      0.74716       2.7113      3.93079E+06  2.07619E+06  3.11365E-02   24.794      0.19410      0.21604
    2 003020000  9.27300E+07  9.31524E+07  6.86744E+07   1.0000      -0.90903       269.57       1.0000      0.00000E+00  6.85650E+05
              0  9.26113E+06  9.30843E+06  6.61368E+06   1.0000       0.34639      3.86389E+05  0.00000E+00   1.0000      2.75790E+06
              2   86.047       1.1155       4.3496      3.93152E+06  2.07620E+06  3.91431E-02   30.864      0.33011      0.20411
    3 003030000  1.38855E+08  1.40346E+08  4.73614E+07   1.0000      -0.60080       169.25       1.0000      0.00000E+00  6.84274E+05
              0  1.12352E+07  1.13291E+07  6.08563E+06   1.0000       0.28548      3.15850E+05  0.00000E+00   1.0000      2.75789E+06
              2  0.58148       1.7971       7.7691      3.93286E+06  2.07622E+06  4.07490E-02   31.104      0.59063      0.18786
0Final volume mass transfer terms
 =====================================================================================================================================
 i     volno      tempf        tempg        tempf-satt   tempg-satt   hif          hig          gammaw       qwf          qwg
 =====================================================================================================================================
    1 003010000   435.64       434.17        1.0766     -0.39032      6.31082E+07  8.86346E+06  8.67051E-03   16.813       123.36
                                                                      4.91436E+07  6.43145E+06
    2 003020000   435.47       434.21       0.90903     -0.34639      9.27300E+07  9.26113E+06  1.32914E-02   25.773       305.77
                                                                      6.86744E+07  6.61368E+06
    3 003030000   435.15       434.26       0.60080     -0.28548      1.38855E+08  1.12352E+07   2.0646      4003.5       293.77
                                                                      6.85443E+07  6.47971E+06
0Other volume terms
 =====================================================================================================================================
 i     volno(i)   viscf(i)     thconf(i)    voidf(i)     fwalf(i)     diamv(i)     costhe(ix)   fidxup(ix)   flomap(ix)   fwfxaf(ix)
       imap(i)    viscg(i)     thcong(i)    voidg(i)     fwalg(i)     dstar(ix)    rvcrit(ix)                pfinrg(ix)   fwfxag(ix)
 =====================================================================================================================================
    1 003010000  1.67492E-04  0.68232      5.48056E-02  5.48056E-02  7.62000E-02 -0.79283      0.00000E+00           12  0.20861
        3162114  1.43039E-05  3.14723E-02  0.94519      0.94519       33.300      0.19410                   0.00000E+00  0.79139
    2 003020000  1.67495E-04  0.68236      6.82091E-02  6.82091E-02  7.62000E-02 -0.75943      0.00000E+00           12  0.22548
        3162114  1.43038E-05  3.14719E-02  0.93179      0.93179       33.303      0.33011                   0.00000E+00  0.77452
    3 003030000  1.67505E-04  0.68243      6.87151E-02  6.87151E-02  7.62000E-02 -0.75821      0.00000E+00           12  0.27787
        3162114  1.43035E-05  3.14708E-02  0.93128      0.93128       33.308      0.59063                   0.00000E+00  0.72213
0#####################################################################################################################################
    phantj Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =       509, help =  3, lsuces =  0, fail = F
0junction drag terms
 =====================================================================================================================================
       junno(i)   fij(i)       c0j(i)       fxj(i)       sinbt(ix)    diamj(i)     faaj(i)      ireg(ix)     voidj(i)     avkx(ix)
       jc(i)      fijo(i)      c0jo(i)      fxjo(i)      vgjj(i)      athrot(i)    jcex(i)      dpstf(ix)    flompj(ix)   avlx(ix)
 =====================================================================================================================================
       003010000  9.90460E-02   1.0000      0.00000E+00  0.00000E+00  7.62000E-02  0.58698                 0  0.94519       1.0000
           65536  9.97859E-02   1.0000      0.00000E+00  0.00000E+00   1.0000          1052768 -0.21658             12   1.0000
       003020000  8.99069E-02   1.0000      0.00000E+00  0.00000E+00  7.62000E-02  0.60980                 0  0.93179       1.0000
           65536  9.09186E-02   1.0000      0.00000E+00  0.00000E+00   1.0000          1052768 -8.79932E-03         12   1.0000
0#####################################################################################################################################
    fwdrag Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =       509, help =  3, lsuces =  0, fail = F
0Volume terms
 ========================================================================================================
       volno(i)   vctrl(i)              voidf(i)     rhof(i)      viscf(i)     diamv(i)     fwalf(i)
                  imap(i)               voidg(i)     rhog(i)      viscg(i)     roughv(i)    fwalg(i)
                                        fshape(i)    frica(i)     fricb(i)     fricc(i)
 ========================================================================================================
       003010000                     0  5.48056E-02   904.81      1.67492E-04  7.62000E-02   2.6663
                               3162114  0.94519       3.3767      1.43039E-05  1.54581E-05  0.17785
                                         1.0000      0.00000E+00  0.00000E+00  0.00000E+00
       003020000                     0  6.82091E-02   904.98      1.67495E-04  7.62000E-02   3.8532
                               3162114  0.93179       3.3760      1.43038E-05  1.54581E-05  0.24982
```

Figure B-1 Diagnostic edit from Edwards pipe problem with extras. (Continued)

```
                                     1.0000      0.00000E+00  0.00000E+00  0.00000E+00
      003030000                  0  6.87151E-02   905.29      1.67505E-04  7.62000E-02   7.2527
                          3162114  0.93128       3.3748      1.43035E-05  1.54581E-05  0.36063
                                     1.0000      0.00000E+00  0.00000E+00  0.00000E+00
0scratch terms, friction factor loop
 ==========================================================================================================================
  nd   volno(i)     sumvfx(l)    fwfaf1(l)    reynf1(l)    fwf1(l)      fwfxaf(l)    reynf2(l)    fwf2(l)      pfinrg(l)
                    sumvgx(l)    fwfag1(l)    reyng1(l)    fwg1(l)      fwfxag(l)    reyng2(l)    fwg2(l)
                    frlmf1(l)    frtrf1(l)    frtbf1(l)    frlmf2(l)    frtrf2(l)    frtbf2(l)
                    frlmg1(l)    frtrg1(l)    frtbg1(l)    frlmg2(l)    frtrg2(l)    frtbg2(l)
 ==========================================================================================================================
   0    003010000   0.74716      5.48056E-02  0.00000E+00  0.00000E+00  0.20861       80803.      2.94681E-03  0.00000E+00
                     3.4585      0.94519      0.00000E+00  0.00000E+00  0.79139       74304.      5.26698E-02
                    0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00   1.0000      1.89062E-02
                    0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00   1.0000      1.92434E-02
   0    003020000    1.1155      6.82091E-02  0.00000E+00  0.00000E+00  0.22548      1.38926E+05  4.25777E-03  0.00000E+00
                     5.4651      0.93179      0.00000E+00  0.00000E+00  0.77452      1.18247E+05  7.39987E-02
                    0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00   1.0000      1.69286E-02
                    0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00   1.0000      1.74822E-02
   0    003030000    1.7971      6.87151E-02  0.00000E+00  0.00000E+00  0.27787      1.83026E+05  8.01149E-03  0.00000E+00
                     9.5662      0.93128      0.00000E+00  0.00000E+00  0.72213      2.21799E+05  0.10686
                    0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00   1.0000      1.60433E-02
                    0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00   1.0000      1.54692E-02
0Wall friction terms, phase apportioning loop
 ==============================================================================
  volno(i)    fwalf(i)                  reynf1(l)    dpdxfx(l)    zambda(l)    tpdpdx(l)
              fwalg(i)     gfwabs(l)    reyng1(l)    dpdxgx(l)    ctermx(l)    ratdpf(l)
              frlmf1(l)    frtrf1(l)    frtbf1(l)    frlmg1(l)    frtrg1(l)    frtbg1(l)
 ==============================================================================
  003010000     31.946                    16856.      4.10283E-02  0.28565       4.7608
                2.1309       48.089       58804.      0.73011       23.052       11.981
              0.00000E+00   1.0000      2.70425E-02  0.00000E+00   1.0000      2.02335E-02
  003020000     52.061                    31325.      0.12210      0.28548       11.661
                3.3754       86.047       91585.       1.6125       22.372       13.511
              0.00000E+00   1.0000      2.33064E-02  0.00000E+00   1.0000      1.84189E-02
  003030000     83.906                    50857.      0.28835      0.28517       29.063
                4.1721      141.86      1.60168E+05   4.4094       21.608       11.569
              0.00000E+00   1.0000      2.08865E-02  0.00000E+00   1.0000      1.64623E-02
0Wall friction terms, heated wall effect
 ==============================================================================
0#################################################################################################################################
     vexplt Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =      509, help =  3, lsuces =  0, fail = F
0Sum and difference terms
 ========================================================================================================================
      junno(i)   sumf         sumg         sumold       diff         difg         difold       avrf         avrg
 ========================================================================================================================
      003010000   11.400      0.65675       10.755      0.34342     -0.34344     -0.93043       55.658       3.1687
      003020000   12.697      0.65277       22.742      0.38092     -0.38094      -2.3173       61.967       3.1443
0volume terms
 ==================================================================================================================================
      volno(i)   dl(i)        voidf(i)     rhof(i)      fwalf(i)     velf(i)      difvfx(ix)   sourcf(ix)   sourcm(ix)   gamas(i)
                 hydzc(i)     voidg(i)     rhog(i)      fwalg(i)     velg(i)      difvgx(ix)   sourcg(ix)   sourca(ix)   enths(i)
 ==================================================================================================================================
      003010000  0.20480      5.48056E-02   904.81       31.946      0.74716      -0.55825      -83.415     5.81609E-05  0.00000E+00
                 0.00000E+00  0.94519       3.3767       2.1309       3.4585       -11.961       83.556     0.00000E+00  0.00000E+00
```

Figure B-1 Diagnostic edit from Edwards pipe problem with extras. (Continued)

```
      003020000  0.20480      6.82091E-02   904.98       52.061       1.1155      -0.41083       -103.79      7.31168E-05  0.00000E+00
                 0.00000E+00  0.93179       3.3760       3.3754       5.4651      -10.966         104.13      0.00000E+00  0.00000E+00
      003030000  0.20480      6.87151E-02   905.29       83.906       1.7971      -0.69333       -103.95      7.61165E-05  0.00000E+00
                 0.00000E+00  0.93128       3.3748       4.1721       9.5662      -19.757         108.25      0.00000E+00  0.00000E+00
0Junction terms
 ====================================================================================================================================
      junno(i)   fij(i)       ajun(i)      arat(i)      fjunf(i)     formfj(i)    velfjo(i)    velgjo(i)    fifj(ix)     vfdpk(ix)
                 fidxup(ix)   athrot(i)    arat(i+1)    fjunr(i)     formgj(i)    velfj(i)     velgj(i)     figj(ix)     vgdpk(ix)
 ====================================================================================================================================
      003010000  9.90460E-02  4.56037E-03   1.0000      0.00000E+00  0.00000E+00  0.74716       3.4585      1.84127E-02  3.61408E-05
                 0.00000E+00   1.0000       1.0000      0.00000E+00  0.00000E+00  0.74449       3.4536      1.84127E-02  8.95301E-04
      003020000  8.99069E-02  4.56037E-03   1.0000      0.00000E+00  0.00000E+00   1.4113       7.5009      3.75312E-02  3.70220E-05
                 0.00000E+00   1.0000       1.0000      0.00000E+00  0.00000E+00   1.4061       7.4892      3.75312E-02  8.11824E-04
0#####################################################################################################################################
     jprop Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =       509, help =  3, lsuces =  0, fail = F
0Junction donored properties, ivrev =  1
 ====================================================================================================================================
      junno(i)   velfj(i)     voidfj(i)    rhofj(i)     qualaj(i)    ufj(i)       jc(i)                      volno(k)   voidgo(k)
                 velgj(i)     voidgj(i)    rhogj(i)     voids        ugj(i)       jcex(i)                    volno(l)   voidgo(l)
 ====================================================================================================================================
      003010000  0.74449      5.48056E-02   904.81      0.00000E+00  6.85683E+05                   65536     003010000  0.94519
                  3.4536      0.94519       3.3767       1.0000      2.56726E+06                 1052768     003020000  0.93179
      003020000   1.4061      6.82091E-02   904.98      0.00000E+00  6.84942E+05                   65536     003020000  0.93179
                  7.4892      0.93179       3.3760       1.0000      2.56734E+06                 1052768     003030000  0.93128
0#####################################################################################################################################
    preseq Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =       509, help =  3, lsuces =  0, fail = F
0Volume terms
 ====================================================================================================================================
 i    volno      po           ufo          ugo          voidgo       qualao       rhof         rhog         sathf        sathg
                 drfdp        drfduf       drgdp        drgdug       drgdxa       dtfdp        dtfduf       dtgdp        dtgdug
                 dtgdxa       dtdp         dtdug        dtdxa        hif          hig          gammaw       qwf          qwg
 ====================================================================================================================================
    1 003010000  6.40546E+05  6.85683E+05  2.56726E+06  0.94519      0.00000E+00   904.81       3.3767      6.81714E+05  2.75790E+06
                 5.01465E-07 -2.27601E-04  5.24610E-06 -5.37932E-06  0.00000E+00  1.20999E-07  2.30226E-04  3.52149E-05  5.39424E-04
                 0.00000E+00  6.18254E-05  0.00000E+00  0.00000E+00  6.31082E+07  8.86346E+06  8.67051E-03   16.813        123.36
    2 003020000  6.40497E+05  6.84942E+05  2.56734E+06  0.93179      0.00000E+00   904.98       3.3760      6.81700E+05  2.75790E+06
                 5.01690E-07 -2.27682E-04  5.24550E-06 -5.37757E-06  0.00000E+00  1.20950E-07  2.30226E-04  3.52149E-05  5.39430E-04
                 0.00000E+00  6.18292E-05  0.00000E+00  0.00000E+00  9.27300E+07  9.26113E+06  1.32914E-02   25.773        305.77
    3 003030000  6.40360E+05  6.83566E+05  2.56745E+06  0.93128      0.00000E+00   905.29       3.3748      6.81664E+05  2.75789E+06
                 5.02101E-07 -2.27828E-04  5.24469E-06 -5.37466E-06  0.00000E+00  1.20855E-07  2.30228E-04  3.52165E-05  5.39447E-04
                 0.00000E+00  6.18397E-05  0.00000E+00  0.00000E+00  1.38855E+08  1.12352E+07   2.0646       4003.5        293.77
0Junction terms
 =============================================================================================================================
      junno(i)   ajun(i)      voidfj(i)    rhofj(i)     ufj(i)       velfjo(i)    velgjo(i)          vfdpk(ix)    vfdpl(ix)
                 qualaj(i)    voidgj(i)    rhogj(i)     ugj(i)       velfj(i)     velgj(i)           vgdpk(ix)    vgdpl(ix)
 =============================================================================================================================
      003010000  4.56037E-03  5.48056E-02   904.81      6.85683E+05  0.74716       3.4585            3.61408E-05  3.61408E-05
                 0.00000E+00  0.94519       3.3767      2.56726E+06  0.74449       3.4536            8.95301E-04  8.95301E-04
      003020000  4.56037E-03  6.82091E-02   904.98      6.84942E+05   1.4113       7.5009            3.70220E-05  3.70220E-05
                 0.00000E+00  0.93179       3.3760      2.56734E+06   1.4061       7.4892            8.11824E-04  8.11824E-04
0Scratch storage volume terms
 ====================================================================================================================================
 i    volno(i)   coefp        sourcf(ix)   sourcm(ix)   a52(ix)      a54(ix)      resoru(ix)   fracal(ix)   fgrw(ix)     fal(ix)
      sourca     sourcp(is)   sourcg(ix)   a51(ix)      a53(ix)      a55(ix)      resorm(ix)   fracag(ix)   a4(ix)       gal(ix)
 ====================================================================================================================================
```

Figure B-1 Diagnostic edit from Edwards pipe problem with extras. (Continued)

```
     1 003010000   3.5213      -83.415      5.81609E-05  0.14896     -1.08748E+05  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
        0.00E+00  -5037.1       83.556      0.00000E+00  1.97906E-02 -1.21660E+05  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
     1 003020000   5.3498      -103.79      7.31168E-05  0.13383      -95718.      0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
        0.00E+00  -5037.2       104.13      0.00000E+00  2.04082E-02 -1.09098E+05  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
     1 003030000   4.7470      -103.95      7.61165E-05  0.11481      -76670.      0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
        0.00E+00  -5037.3       108.25      0.00000E+00  2.41167E-02  -92623.      0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
0#####################################################################################################################################
     syssol Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =       509, help =  3, lsuces =  0, fail = F
0Pressure matrix
 ======================================================================================================================
 eq.no. volno    el.no.  coefp      el.no.  coefp      el.no.  coefp      el.no.  coefp      el.no.  coefp       dia.dom.term
 ======================================================================================================================
      1 003010000     1   3.5213        2  -2.5213
+                                                                                                                  1.0000
      2 003020000     1  -2.2958        2   5.3498        3  -2.0540
+                                                                                                                 1.00000
      3 003030000     2  -1.8424        3   4.7470        4  -1.9046
+                                                                                                                 1.00000
      4 003040000     3  -1.7625        4   4.6387        5  -1.8762
+                                                                                                                  1.0000
      5 003050000     4  -1.8671        5   4.8086        6  -1.9415
+                                                                                                                 1.00000
      6 003060000     5  -1.9655        6   5.0072        7  -2.0417
+                                                                                                                  1.0000
      7 003070000     6  -2.0705        7   5.2225        8  -2.1520
+                                                                                                                  1.0000
      8 003080000     7  -2.1856        8   5.4555        9  -2.2699
+                                                                                                                  1.0000
      9 003090000     8  -2.3072        9   5.6968       10  -2.3896
+                                                                                                                 1.00000
     10 003100000     9  -2.4286       10   5.9334       11  -2.5048
+                                                                                                                 1.00000
     11 003110000    10  -2.5434       11   6.1544       12  -2.6110
+                                                                                                                  1.0000
     12 003120000    11  -2.6474       12   6.3530       13  -2.7056
+                                                                                                                 1.00000
     13 003130000    12  -2.7390       13   6.5272       14  -2.7881
+                                                                                                                 1.00000
     14 003140000    13  -2.8182       14   6.6774       15  -2.8592
+                                                                                                                  1.0000
     15 003150000    14  -2.8858       15   6.8057       16  -2.9198
+                                                                                                                  1.0000
     16 003160000    15  -2.9431       16   6.9144       17  -2.9712
+                                                                                                                  1.0000
     17 003170000    16  -2.9912       17   7.0048       18  -3.0136
+                                                                                                                  1.0000
     18 003180000    17  -3.0287       18   7.0786       19  -3.0499
+                                                                                                                  1.0000
     19 003190000    18  -3.0654       19   7.1417       20  -3.0763
+                                                                                                                  1.0000
     20 003200000    19  -3.0709       20   4.1547       21  0.00000E+00
+                                                                                                                  1.0838
     21 005010000    21   1.0000
+                                                                                                                  1.0000
0Solution array
```

Figure B-1 Diagnostic edit from Edwards pipe problem with extras. (Continued)

```
 ==================================================================================================================
       sourcp(i)    sourcp(i+1)  sourcp(i+2)  sourcp(i+3)  sourcp(i+4)  sourcp(i+5)  sourcp(i+6)  sourcp(i+7)  sourcp(i+8)
 ==================================================================================================================
       -5036.2      -5035.9      -5034.8      -5032.5      -5027.1      -5020.9      -5012.3      -5000.5      -4985.0
       -4965.1      -4940.4      -4910.7      -4875.5      -4834.5      -4787.4      -4733.7      -4672.8      -4604.5
       -4529.4      -4443.0      0.00000E+00
0Singularity parameter (if gerr .lt. 0.0, the matrix solution is singular)
 gerr =  1.00000E-12
0###########################################################################################################################
      jprop Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =      509, help =  3, lsuces =  0, fail = F
0Junction donored properties, ivrev =  1
 ===========================================================================================================================
      junno(i)  velfj(i)     voidfj(i)    rhofj(i)     qualaj(i)    ufj(i)       jc(i)                      volno(k)   voidgo(k)
                velgj(i)     voidgj(i)    rhogj(i)     voids        ugj(i)       jcex(i)                    volno(l)   voidgo(l)
 ===========================================================================================================================
      003010000 0.74448      5.48056E-02   904.81      0.00000E+00  6.85683E+05               65536         003010000  0.94519
                 3.4533      0.94519       3.3767       1.0000      2.56726E+06             1052768         003020000  0.93179
      003020000  1.4061      6.82091E-02   904.98      0.00000E+00  6.84942E+05               65536         003020000  0.93179
                 7.4883      0.93179       3.3760       1.0000      2.56734E+06             1052768         003030000  0.93128
0###########################################################################################################################
      vfinl Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =      509, help =  3, lsuces =  0, fail = F
0Final junction velocities and flows
 ==========================================================================================================================
      junno(i)  flag         ajun(i)      voidfj(i)    rhofj(i)     velfj(i)          vfdpk(j)     vgdpk(j)       k   p(k)-po(k)
                             mflowj(i)    voidgj(i)    rhogj(i)     velgj(i)          vfdpl(j)     vgdpl(j)       l   p(l)-po(l)
 ==========================================================================================================================
      003010000              4.56037E-03  5.48056E-02   904.81      0.74448           3.61408E-05  8.95301E-04    1   -5036.2
                             0.21862      0.94519       3.3767       3.4533           3.61408E-05  8.95301E-04    2   -5035.9
      003020000              4.56037E-03  6.82091E-02   904.98       1.4061           3.70220E-05  8.11824E-04    2   -5035.9
                             0.50325      0.93179       3.3760       7.4883           3.70220E-05  8.11824E-04    3   -5034.8
0###########################################################################################################################
     eqfinl Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =      509, help =  3, lsuces =  0, fail = F
0Common junction data
 ===============================================================================================================
 junno         i  ajun(i)      voidfj(i)    rhofj(i)     velfj(i)     ufj(i)       conmf(i)     cond(i)      conm(i)
                  qualaj(i)    voidgj(i)    rhogj(i)     velgj(i)     ugj(i)       conmg(i)
 ===============================================================================================================
 003010000     1  4.56037E-03  5.48056E-02   904.81      0.74448      6.85683E+05  1.68358E-04 -1.18094E-04  2.18621E-04
                  0.00000E+00  0.94519       3.3767       3.4533      2.56726E+06  5.02632E-05
 003020000     2  4.56037E-03  6.82091E-02   904.98       1.4061      6.84942E+05  3.95821E-04 -2.88394E-04  5.03247E-04
                  0.00000E+00  0.93179       3.3760       7.4883      2.56734E+06  1.07427E-04
0From-to contributions to source terms
 ===============================================================================================================
 junno         i            k  scv2(i)      scv3(i)      scv4(i)              l  scv2(i)      scv5(i)      scv6(i)
 ===============================================================================================================
 003010000     1            1  0.00000E+00   138.57       115.56              2  0.00000E+00   138.57       115.56
 003020000     2            2  0.00000E+00   296.18       271.39              3  0.00000E+00   296.18       271.39
0###########################################################################################################################
     eqfinl Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =      509, help =  3, lsuces =  0, fail = F
0Volume data
 ===========================================================================================================================
 volno         i  sourcf(i)    sourcm(i)    sorp(i)      po(i)        ugo(i)       ufo(i)       voidgo(i)    qualao(i)    rhom(i)
                  sourcg(i)    sourca(i)    delxa(i)     p(i)         ug(i)        uf(i)        voidg(i)     quala(i)     dotm(i)
 ===========================================================================================================================
 003010000     1  -198.97      1.76255E-04 -2.18621E-04  6.40546E+05  2.56726E+06  6.85683E+05  0.94519      0.00000E+00   52.546
```

Figure B-1 Diagnostic edit from Edwards pipe problem with extras. (Continued)

```
                 -55.018      0.00000E+00  0.00000E+00  6.35510E+05  2.56700E+06  6.84312E+05  0.94545      0.00000E+00   30.998
 003020000     2  -259.63      2.43416E-04 -2.84626E-04  6.40497E+05  2.56734E+06  6.84942E+05  0.93179      0.00000E+00   64.569
                 -53.483      0.00000E+00  0.00000E+00  6.35461E+05  2.56708E+06  6.83576E+05  0.93213      0.00000E+00   39.004
 003030000     3  -253.84      2.37021E-04 -2.78766E-04  6.40360E+05  2.56745E+06  6.83566E+05  0.93128      0.00000E+00   65.052
                 -54.253      0.00000E+00  0.00000E+00  6.35325E+05  2.56719E+06  6.82223E+05  0.93161      0.00000E+00   38.838
0#####################################################################################################################################
      state Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =       509, help =  3, lsuces =  0, fail = F
0Volume mixture properties
 =====================================================================================================================================
       volno      v            p            voidf        quals        dotm         quala        boron        sounde       rho
                  vo           pps          voidg        quale        dotmo        sigma        borono       dsnddp       satt
 =====================================================================================================================================
       003010000  9.33968E-04  6.35510E+05  5.45534E-02  6.03053E-02   30.998      0.00000E+00  0.00000E+00   79.335       52.546
                  9.33968E-04  6.35510E+05  0.94545      6.25989E-02   31.269      4.63559E-02  0.00000E+00  2.75661E+06   434.25
       003020000  9.33968E-04  6.35461E+05  6.78738E-02  4.83754E-02   39.004      0.00000E+00  0.00000E+00   67.194       64.569
                  9.33968E-04  6.35461E+05  0.93213      5.03408E-02   39.358      4.63566E-02  0.00000E+00  2.75672E+06   434.24
       003030000  9.33968E-04  6.35325E+05  6.83870E-02  4.79717E-02   38.838      0.00000E+00  0.00000E+00   66.100       65.052
                  9.33968E-04  6.35325E+05  0.93161      4.92771E-02   39.178      4.63584E-02  0.00000E+00  2.75685E+06   434.24
0Volume phase properties
 =====================================================================================================================================
       volno      rhof         uf           tempf        sathf        betaff       kapaff       csubpf       viscf        thconf
                  rhog         ug           tempg        sathg        betagg       kapagg       csubpg       viscg        thcong
 =====================================================================================================================================
       003010000   905.12      6.84312E+05   435.32      6.80358E+05  1.09072E-03  6.85176E-10   4343.4      1.67836E-04  0.68239
                   3.3517      2.56700E+06   433.86      2.75755E+06  2.95193E-03  1.67015E-06   2411.4      1.42928E-05  3.14311E-02
       003020000   905.29      6.83576E+05   435.15      6.80345E+05  1.09090E-03  6.85288E-10   4343.4      1.67840E-04  0.68243
                   3.3510      2.56708E+06   433.90      2.75755E+06  2.95154E-03  1.67027E-06   2411.4      1.42927E-05  3.14307E-02
       003030000   905.60      6.82223E+05   434.84      6.80308E+05  1.09121E-03  6.85481E-10   4343.4      1.67849E-04  0.68250
                   3.3497      2.56719E+06   433.95      2.75754E+06  2.95098E-03  1.67062E-06   2411.3      1.42924E-05  3.14296E-02
0Derivatives
 =====================================================================================================================================
       volno      drfdp        drfduf       drgdp        drgdug       drgdxa       dtfdp        dtfduf       dtgdp        dtgdug
                  dtgdxa       dtdp         dtdug        dtdxa
 =====================================================================================================================================
       003010000  5.01022E-07 -2.27333E-04  5.24814E-06 -5.34321E-06  0.00000E+00  1.20687E-07  2.30274E-04  3.53392E-05  5.40052E-04
                  0.00000E+00  6.22143E-05  0.00000E+00  0.00000E+00
       003020000  5.01245E-07 -2.27413E-04  5.24754E-06 -5.34148E-06  0.00000E+00  1.20637E-07  2.30274E-04  3.53391E-05  5.40058E-04
                  0.00000E+00  6.22182E-05  0.00000E+00  0.00000E+00
       003030000  5.01647E-07 -2.27556E-04  5.24675E-06 -5.33861E-06  0.00000E+00  1.20545E-07  2.30276E-04  3.53408E-05  5.40075E-04
                  0.00000E+00  6.22287E-05  0.00000E+00  0.00000E+00
0#####################################################################################################################################
   mass err Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =       509, help =  3, lsuces =  0, fail = F
0Volume properties
 ==============================================================================================
       volno      v            rho          rhom         drho/rhof    drho/rho     v*drho
 ==============================================================================================
       003010000  9.33968E-04   52.546       52.546      1.02192E-07  1.76028E-06  8.63885E-08
       003020000  9.33968E-04   64.569       64.569      1.11559E-07  1.56411E-06  9.43242E-08
       003030000  9.33968E-04   65.052       65.052      7.06268E-08  9.83209E-07  5.97360E-08
 ----------------------------------------------------------------------------------------------
 System mass error increment for this time step----------------------------------  1.17019E-07
 Mass + flow in - flow out mass error increment---------------------------------- -1.64825E-03
 Mean mass error increment-------------------------------------------------------  6.26460E-06
 Rms mass error increment--------------------------------------------------------  1.73157E-03
 Mean mass error fraction--------------------------------------------------------  1.46810E-07
```

Figure B-1 Diagnostic edit from Edwards pipe problem with extras. (Continued)

```
 Rms mass error fraction--------------------------------------------------------  8.75055E-07
 Max. system or overall global mass error tolerance------------------------------  1.75966E-06
 Controlling errmax--------------------------------------------------------------  1.76028E-06
0################################################################################################################################
     jprop Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =      509, help =  3, lsuces =  0, fail = F
0Junction donored properties, ivrev =  0
 ================================================================================================================================
      junno(i)   velfj(i)     voidfj(i)    rhofj(i)     qualaj(i)    ufj(i)       jc(i)                      volno(k)    voidg(k)
                 velgj(i)     voidgj(i)    rhogj(i)     voids        ugj(i)       jcex(i)                    volno(l)    voidg(l)
 ================================================================================================================================
      003010000  0.74448      5.45534E-02   905.12      0.00000E+00  6.84312E+05                 65536       003010000  0.94545
                  3.4533      0.94545       3.3517       1.0000      2.56700E+06               1052768       003020000  0.93213
      003020000   1.4061      6.78738E-02   905.29      0.00000E+00  6.83576E+05                 65536       003020000  0.93213
                  7.4883      0.93213       3.3510       1.0000      2.56708E+06               1052768       003030000  0.93161
0################################################################################################################################
    vlvela Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =      509, help =  3, lsuces =  0, fail = F
0Volume inlet and outlet terms
 ===============================================================================================================
       volno(i)             invcnt(l)
       avol(i)     iiflag   loop jx    junno(jx)  ivf ajun(jx)     voidfj(jx)   rhofj(jx)    velfj*ivf    arat(jx)
                                                      athrot(jx)   voidgj(jx)   rhogj(jx)    velgj*ivf    arat(jx+1)
 ===============================================================================================================
       003010000            1
       4.56037E-03
+                  outlet   1          003010000  1   4.56037E-03  5.45534E-02   905.12      0.74448       1.0000
                                                       1.0000      0.94545       3.3517       3.4533       1.0000
       003020000            2
       4.56037E-03
+                  inlet    1          003010000  1   4.56037E-03  5.45534E-02   905.12      0.74448       1.0000
                                                       1.0000      0.94545       3.3517       3.4533       1.0000
                   outlet   2          003020000  1   4.56037E-03  6.78738E-02   905.29       1.4061       1.0000
                                                       1.0000      0.93213       3.3510       7.4883       1.0000
       003030000            2
       4.56037E-03
+                  inlet    1          003020000  1   4.56037E-03  6.78738E-02   905.29       1.4061       1.0000
                                                       1.0000      0.93213       3.3510       7.4883       1.0000
                   outlet   2          003030000  1   4.56037E-03  6.83870E-02   905.60       2.1702       1.0000
                                                       1.0000      0.93161       3.3497       11.607       1.0000
0Volume average terms
 ==========================================================================================
       volno(i)   velf(i)      vvfx(ix)     vvfx(ix+1)   vrhof(ix)    vrhof(ix+1)  areav(ix)
                  velg(i)      vvgx(ix)     vvgx(ix+1)   vrhog(ix)    vrhog(ix+1)  areav(ix+1)
 ==========================================================================================
       003010000  0.74448      0.00000E+00  0.16764      0.00000E+00  0.22518      0.00000E+00
                   3.4533      0.00000E+00  4.99035E-02  0.00000E+00  1.44510E-02  4.56037E-03
       003020000   1.1113      0.16764      0.39401      0.22518      0.28021      4.56037E-03
                   5.4563      4.99035E-02  0.10667      1.44510E-02  1.42445E-02  4.56037E-03
       003030000   1.7897      0.39401      0.61292      0.28021      0.28243      4.56037E-03
                   9.5467      0.10667      0.16518      1.42445E-02  1.42313E-02  4.56037E-03
0################################################################################################################################
   ms err t Diagnostic printout, timehy =  0.5000000    , dt =  1.0000000E-03, ncount =      509, help =  3, succes =  0, fail = F
 ------------------------------------------------------------------------------------------
 Total mass error increment for this time step-----------------------------------  1.17019E-07
 Mass + flow in - flow out mass error increment---------------------------------- -1.17019E-07
 Mean mass error increment-------------------------------------------------------  6.26460E-06
```

Figure B-1 Diagnostic edit from Edwards pipe problem with extras. (Continued)

.

```
Rms mass error increment-------------------------------------------------------  1.73157E-03
Mean mass error fraction-------------------------------------------------------  1.46810E-07
Rms mass error fraction--------------------------------------------------------  8.75055E-07
Max. system or overall global mass error tolerance-----------------------------  1.75966E-06
Controlling errmax-------------------------------------------------------------  1.76028E-06
```

Figure B-1 Diagnostic edit from Edwards pipe problem with extras. (Continued)

```
 .
*comdeck jundatc
c
c  ijskp   junction skip factor.
c  njuns   number of junctions
c  ij1     from volume input code.
c  ij2     to volume input code.
c  jc      choking flag (1 bit); time dependent junction flag (2 bit);
c          reversed from volume connection flag (4 bit); reversed to
c          volume connection flag (8 bit); no choking flag (16 bit);
c          old time choking flag (32 bit); choking test flag for
c          accumulator junction (64 bit); input flag (128 bit); abrupt
c          area change flag (256 bit); two velocity-one velocity flag
c          (512 bit); separator flag (1024 bit); stratified flow flag
c          (2048 bit); from cross flow option (4096 bit); to cross flow
c          option (8192 bit); cross flow flag (16384 bit); accumulator
c          active flag (32768 bit); stratification flag (65536 bit);
c          stratification input data (bit pos. 18-19); jet mixer flags
c          (bit pos. 20-22); separator flags (bit pos. 23-25);
c          unused (bit pos. 26); horiz-vert junction flag (bit pos.27);
c          up-down junction flag (bit pos. 28); valve flag (bit
c          pos. 29); second turbine junction flag (bit pos. 30).
c  ij1vn   from volume ordinal number.
c  ij2vn   to volume ordinal number.
c  junftl(1)  from pointer in output form without sign.
c  junftl(2)  to pointer in output form without sign.
c  ajun    area of junction
c  athrot  ratio of orifice area to junction area
c  arat(1) mixture volumetric flow rate for the junction divided by
c          the total mixture volumetric flow rate on that end of the
c          volume.  mixture is obtained by using sum of absolute value
c          of phasic volumetric flow rates. 1 is for "from" volume.
c  arat(2) same as arat(1), except 2 is for "to" volume.
c  diamj   diameter of junction
c  ******  warning: the ordering of velfj, velfjo, velgj, velgjo, ufj,
c  ******  ugj, voidfj, voidgj, qualaj, rhofj, and rhogj must be
c  ******  maintained since vfinl assumes this order.
c  velfj   liquid velocity
c  velfjo  liquid velocity previous time step
c  velgj   vapor velocity
c  velgjo  vapor velocity previous time step
c  ufj     junction liquid specific internal energy
c  ugj     junction vapor specific internal energy
c  voidfj  junction liquid void fraction
c  voidgj  junction vapor void fraction
c  qualaj  junction noncondensible quality
c  rhofj   junction liquid density
c  rhogj   junction vapor density
c  velfjs  intermediate liquid velocity used when have bad donoring
c  velgjs  intermediate vapor velocity used when have bad donoring
c  fjunf   Constant term for form loss coefficient for irreversible
c          losses, foward.
c  fjunr   Constant term for form loss coefficient for irreversible
c          losses, reverse.
c  fjunfb  Multipler term for form loss coefficient for irreversible
c          losses, foward.
```

Figure B-2 Listing of common block JUNDATC from program ATHENA.

```
.
c  fjunfc  Exponent term for form loss coefficient for irreversible
c          losses, foward.
c  fjunrb  Multipler term for form loss coefficient for irreversible
c          losses, reverse.
c  fjunrc  Exponent term for form loss coefficient for irreversible
c          losses, reverse.
c  formfj  liquid form loss term
c  formgj  vapor form loss term
c  mflowj  mass flow rate
c  faaj    virtual mass
c  fij     interphase friction
c  fijo    interphase friction previous time step
c  jcatn   density correction factor (sqrt of rhot/rhoj) applied to
c          the junction convective term in choking
c  jacto   density correction factor applied to the junction convective
c          term in choking previous time step
c  qualnj(1)  first noncondensible junction mass fraction
c  qualnj(2)  second noncondensible junction mass fraction
c  qualnj(3)  third noncondensible junction mass fraction
c  qualnj(4)  fourth noncondensible junction mass fraction
c  qualnj(5)  fifth noncondensible junction mass fraction
c  ij1nx   from volume index.
c  ij2nx   to volume index.
c  jcnx1   index to scratch space for "from" volume.  next word is
c          same for "to" volume.
c  jcnx2   index to diagonal matrix element for "from" volume.  next
c          word is same for "to" volume.
c  jcnx3   index to off-diagonal matrix element for "from" volume. next
c          word is same for "to" volume.
c  jcnxd(1)  diagonal index for sum momentum equation
c  jcnxd(2)  diagonal index for difference momentum equation
c  jcnxs   index to scratch space for junction.
c  junno   junction number for output editing
c  jdissc  subcooled discharge coefficient.
c  jdistp  two phase discharge coefficient.
c  jcex    unused (bit pos. 1); ccfl flag (bit pos. 2);
c          input ccfl flag (bit pos. 3); junction flow regime number
c          (bit pos. 4-9); to face-1 bits (bit pos. 10-12); from face-1
c          bits (bit pos. 13-15); input donor pressure flag
c          (bit pos. 16); water packer junction flag (bit pos. 17);
c          stretch junction flag (bit pos. 18); eccmix flags (bit
c          pos. 19-20); debug print flag (bit pos. 21),
c          water packing flag(bit pos. 22).
c  betacc  form of ccfl correlation (0 = wallis, 1 = kutateladze)
c  constc  gas intercept for ccfl correlation
c  constm  slope for ccfl correlation
c  c0j     junction distribution coefficient
c  c0jo    junction distribution coefficient previous time step
c  xej     junction equilibrium quality
c          based on extrapolated pressure & internal energy from jchoke
c  sonicj  junction sound speed
c          divided by the junction density ratio (jcatn)
c  vodfjo  junction liquid void fraction previous timestep
c  vodgjo  junction vapour void fraction previous timestep
c  vdfjoo  junction liquid void fraction previous timestep but one
```

Figure B-2 Listing of common block JUNDATC from program ATHENA. (Continued)

```
  .
c  vdgjoo  junction vapour void fraction previous timestep but one
c  fxj     wall friction interpolating factor
c  fxjo    wall friction interpolation factor previous time step
c  vgjj    vapor drift velocity
c  florgj  junction flow regime number in real format
c  iregj   vertical bubbly/slug flow junction flow regime number in
c          real format
c  voidj   junction vapor void fraction used in the interphase drag
c  jdissh  superheated discharge coefficient
c  ijflg   Junction direction flag (0 = 1D/1D or 1D/3D or 3D/1D,
c          1 = 3D/3D direction 1, 2 = 3D/3D direction 2, 3 = 3D/3D
c          direction 3).
c  flenth  Total enthalpy flow in junction (includes both phases and
c          noncondensibles).
$if def,selap,2
c  ajuno   Old ajun.
c  diamjo  Old diamj.
```

Figure B-2 Listing of common block JUNDATC from program ATHENA. (Continued)

```
  .
*comdeck voldatc
c
c  ivskp   volume skip factor.
c  nvols   number of volumes.
c  vctrl   time dependent volume flag (bit pos. 1); equilibrium flag
c          (bit pos. 2); thermal front flag (bit pos. 3); input flag
c          (bit pos. 4); vapor disappearance flag (bit pos. 5);
c          accumulator flag (bit pos. 6); pump flag (bit pos. 7);
c          input water packer flag (bit pos. 8); new status flags,
c          initialization type during input (bit pos. 9-19);
c          old status flags (bit pos. 20-30); input bundle flag
c          (bit pos. 31).
c          Status flags: negative pressure (bits 9, 20); mass error
c          (bits 10, 21); extrapolation error (bits 11, 22); quality
c          overrun (bits 12, 23); largest mass error (bits 13, 24);
c          error in vapor phase (bits 14, 25); error in liquid phase
c          (bits 15, 26); error in two phase call (bits 16, 27); non-
c          convergence in iterations (bits 17, 28); negative sonic
c          velocity (bits 18, 29); negative derived quantities (bits 19,
c          30).
c  vctrlx  Status flags; debug print flag (bit pos. 1), air appearance
c          repeat(bit pos. 2), pressure change repeat on air appearance
c          (bit pos. 3 ), water packing statistics flag( bit pos. 4).
c  volmat  Fluid type in volume.
c  volno   Volume number for editing.
c  imap    Map, regime, and flags.  Three quantities, one per
c          coordinate.  Flow regime map infomation (bit pos. 1-6);
c          non-condensable gas appearance flag (bit pos. 7);
c          horizontal stratification flag (bit pos. 8);
c          (bit pos. 8); stretch flag (bit pos. 9); input vertical
c          stratification flag (bit pos. 10); vertical stratification
c          flags (bit pos. 11-12); experimental friction being used
c          (bit pos. 13); wall friction input flag (bit pos. 14); flag
c          that coordinate direction is being used (bit pos. 15); water
c          packer input flag (bit pos. 16); bundle input flag
c          (bit pos. 17); volume in multid component (bit pos. 18);
c          flow  regime number (bit pos. 19-24); metal appearance flags
c          (bit pos. 25-26); laminar friction factor, 64 if 0, 96 if 1
c          (bit pos. 27); ans input flag (bit pos. 28); level tracking
c          input flag (bit pos. 29);  reflood flag (bit pos. 30);
c          water packer  volume flag (bit pos. 31).
c  v       Volume.
c  recipv  Reciprocal of volume (v), zero if v is zero.
c  avol    Area of volume, three quantities, one per coordinate.
c  dl      Volume length, three quantities, one per coordinate.
c  diamv    Equivalent flow diameter, three quantities, one per
c           coordinate.
c  roughv    Wall roughness factor for direction 1.  As input
c            reset in icmpn1 to colebrook full turb friction fac.
c  recrit     Critical reynolds number, three quantities, one per
c             coordinate.  Fric fac = const; see roughv.
c  p       Average pressure.
c  po      Average pressure previous time step.
c  uf      Liquid specific internal energy.
c  ufo     Liquid specific internal energy previous time step.
```

Figure B-3 Listing of common block VOLDATC from program ATHENA.

```
     .
c  ug      vapor specific internal energy.
c  ugo     vapor specific internal energy previous time step.
c  voidf   liquid void fraction.
c  voidg   vapor void fraction.
c  voidgo  vapor void fraction previous time step (n).
c  vodgoo  vapor void fraction at old old time step (n-1).
c  quala   noncondensible quality..
c  qualao  noncondensible quality previous time step.
c  boron   boron density (mass of boron per cell volume).
c  borono  boron density previous time step.
c  quals   static quality.
c  quale   equilibrium quality.
c  rho     total density.
c  rhom    total density for mass error check.
c  rhoo    total density previous time step.
c  ******  warning: the ordering of rhof and rhog must be maintained
c  ******  since fidis assumes this order.
c  rhof    liquid density.
c  rhog    vapor density.
c  satt    saturation temperature based on the steam partial pressure.
c  temp    used in r level subroutines and is usually the same as satt.
c  tempf   liquid temperature.
c  tempg   vapor temperature.
c  velf(1) Average liquid velocity in a volume, three quantities, one
c          per coordinate.
c  velg    Average vapor velocity in a volume, three quantities, one per
c          coordinate.
c  sounde  homogeneous equilibrium sound speed. also, used for scratch
c          in hydro.
c  dsnddp  partial derivative of sounde w/r to pressure. also, used for
c          scratch in hydro.
c  sathf   liquid specific enthalpy at saturation conditions.
c  sathg   vapor specific enthalpy at saturation conditions.
c  betaff  Liquid isobaric coefficient of thermal expansion at bulk
c          conditions.
c  betagg  Vapor isobaric coefficient of thermal expansion at bulk
c          conditions.
c  csubpf  Liquid specific heat capacity at constant pressure at bulk
c          conditions.
c  csubpg  Vapor specific heat capacity at constant pressure at bulk
c          conditions.
c  viscf   Liquid viscosity.
c  viscg   Vapor viscosity.
c  sigma   Surface tension.
c  thconf  Liquid thermal conductivity.
c  thcong  Vapor thermal conductivity.
c  pps     Vapor partial pressure.
c  dotm    Vapor generation rate per unit volume.
c  dotmo   Vapor generation rate per unit volume previous time step.
c  hif     Liquid side interfacial heat transfer coefficient per unit
c          volume.
c  hig     Vapor side interfacial heat transfer coefficient per unit
c          volume.
c  gammaw  Vapor generation rate at the wall per unit volume.
c  q       total heat transfer rate from wall to fluid.
```

Figure B-3 Listing of common block VOLDATC from program ATHENA. (Continued)

```
  .
c  qwg     heat transfer rate from wall to vapor.
c  drfdp   partial derivative of rhof w/r to pressure.
c  drfduf  partial derivative of rhof w/r to liquid specific internal
c          energy.
c  drgdp   partial derivative of rhog w/r to pressure.
c  drgdug  partial derivative of rhog w/r to vapor specific internal
c          energy.
c  drgdxa  partial derivative of rhog w/r to noncondensible quality.
c  dtfdp   partial derivative of tempf w/r to pressure.
c  dtfduf  partial derivative of tempf w/r to liquid specific internal
c          energy.
c  dtgdp   partial derivative of tempg w/r to pressure.
c  dtgdug  partial derivative of tempg w/r to vapor specific internal
c          energy.
c  dtgdxa  partial derivative of tempg w/r to noncondensible quality.
c  dtdp    partial derivative of satt w/r to pressure.
c  dtdug   partial derivative of satt w/r to vapor specific internal
c          energy.
c  dtdxa   partial derivative of satt w/r to noncondensible quality.
c  floreg  flow regime number in real format, three quantities, one per
c          coordinate.
c  hifo    liquid side interfacial heat transfer coefficient per unit
c          volume previous timestep.
c  higo    vapor side interfacial heat transfer coefficient per unit
c          volume previous timestep.
c  qualan  Noncondensible mass fraction, five quantities, one per
c          species.
c  gaman   Noncondensible generation rate per unit volume,
c          five quantities, one per species.
c  enthn   Enthalpy of noncondensible source, five quantities, one per
c          species.
c  gamas   solute generation rate per unit volume.
c  enths   enthalpy of the solute source.
c  vo      volume previous time step.
c  qualno  Noncondensible mass fraction previous time step, five
c          quantities, one per species.
c  rhogo   vapor density previous time step.
c  ppso    vapor partial pressure (old-time).
c  ustm    vapor specific internal energy at pps and tempg with non-
c          condensable present.
c  ustmo   vapor specific internal energy at pps and tempg with non-
c          condensable present (old-time).
c  ggas    Cell centered gas mass flux, three quantities, one per
c          coordinate.
c  gliq    Cell centered liquid mass flux, three quantities, one per
c          coordinate.
c  velfo   Volume average liquid velocity previous timestep, three
c          quantities, one per coordinate.
c  velgo   Volume average vapor velocity previous timestep, three
c          quantities, one per coordinate.
c  fstrt   horizontal stratification interpolating factor, three
c          quantities, one per coordinate.
c  fwalf   liquid wall friction coefficient, three quantities, one per
c          coordinate.
c  fwalg   vapor wall friction coefficient, three quantities, one per
```

Figure B-3 Listing of common block VOLDATC from program ATHENA. (Continued)

```
     .
c          coordinate.
c  vctrln  position of volume in volume block.
c  vctrld  index to diagonal matrix element.
c  vctrls  index to volume scratch space.
c  sth2xv  index data for sth2x water property subroutines.
c  invfnd  index to inverted junction table.
c  sinb    sine function of volume vertical angle, three quantities, one
c          per coordinate.
c  hvmix   volume mixture enthalpy.
c  ptans   pitch between fuel plates (ans).
c  span    length of fuel plates  (ans).
c  pecltv  Volume Peclet number, three quantities, one per coordinate.
c  tsatt   saturation temperature based on the total pressure.
c  fshape  Wall friction shape factor (one per coordinate).
c  fmurex  Viscosity ratio for wall friction (one per coordinate).
c  hgf     Direct heating heat transfer coefficient per unit volume.
c  frica   Constant term in experimental friction correlation (one per
c          coordinate).
c  fricb   Multiplier term in experimental friction correlation (one per
c          coordinate).
c  fricc   Power term in experimental friction correlation (one per
c          coordinate).
c  invhtf  index to inverted heat structure table.
c  hydxc(1)  Change along inertial x axis due to moving from face 1
c            to center of volume along local x coordinate.
c  hydxc(2)  Change along inertial x axis due to moving from center of
c            volume to face 2 along local x coordinate.
c  hydxc(3)  Change along inertial x axis due to moving from face 3
c            to center of volume along local y coordinate.
c  hydxc(4)  Change along inertial x axis due to moving from center of
c            volume to face 4 along local y coordinate.
c  hydxc(5)  Change along inertial x axis due to moving from face 5
c            to center of volume along local z coordinate.
c  hydxc(6)  Change along inertial x axis due to moving from center of
c            volume to face 6 along local z coordinate.
c  hydyc(1)  Change along inertial y axis due to moving from face 1
c            to center of volume along local x coordinate.
c  hydyc(2)  Change along inertial y axis due to moving from center of
c            volume to face 2 along local x coordinate.
c  hydyc(3)  Change along inertial y axis due to moving from face 3
c            to center of volume along local y coordinate.
c  hydyc(4)  Change along inertial y axis due to moving from center of
c            volume to face 4 along local y coordinate.
c  hydyc(5)  Change along inertial y axis due to moving from face 5
c            to center of volume along local z coordinate.
c  hydyc(6)  Change along inertial y axis due to moving from center of
c            volume to face 6 along local z coordinate.
c  hydzc(1)  Change along inertial z axis due to moving from face 1
c            to center of volume along local x coordinate.
c  hydzc(2)  Change along inertial z axis due to moving from center of
c            volume to face 2 along local x coordinate.
c  hydzc(3)  Change along inertial z axis due to moving from face 3
c            to center of volume along local y coordinate.
c  hydzc(4)  Change along inertial z axis due to moving from center of
c            volume to face 4 along local y coordinate.
```

Figure B-3 Listing of common block VOLDATC from program ATHENA. (Continued)

```
   .
c  hydzc(5)  Change along inertial z axis due to moving from face 5
c            to center of volume along local z coordinate.
c  hydzc(6)  Change along inertial z axis due to moving from center of
c            volume to face 6 along local z coordinate.
c  hyposv(1)  Coordinate along x inertial axis of vector from center
c             of rotation to center of volume.
c  hyposv(2)  Coordinate along y inertial axis of vector from center
c             of rotation to center of volume.
c  hyposv(3)  Coordinate along z inertial axis of vector from center
c             of rotation to center of volume.
c  gravv(1)  Coordinate of gravity along inertial x coordinate.
c  gravv(2)  Coordinate of gravity along inertial y coordinate.
c  gravv(3)  Coordinate of gravity along inertial z coordinate.
c  tintf     Interface temperature when noncondensible is presentR,
c            saturation temperature at total pressure otherwise.
c  htsens    Heat transfer coefficient for sensible heat transfer
c            between vapor/gas mixture and liquid.
c  tmassv    Total mass (includes both phases and noncondensibles) in
c            volume.
c  tiengv    Total internal energy (of both phases and noncondensibles)
c            in volume.
$if def,selap
c  idbvol  indicator of whether l-th index of relap5 volume contains
c          debris region; 0 = no, 1 = yes.
c  mdbvol  value for l-th relap5 volume index of index m for
c          referencing arrays in common block debcom.
c  ndbvol  value for l-th relap5 volume index of index n for
c          referencing arrays in common block debcom.
$if def,athena
c  bfield  strength of magnetic field acting on volume.
c  econdw  electrical conductivity of duct wall.
c  fwfmhd  equivalent wall friction coefficient due to mhd effects.
c  hwidth  duct half-width.
c  wthick  thickness of duct wall.
c  igmhd   duct geometry type; 1=circular, 2=rectangular.
$endif
c  avolo   Old value of avol.
c  diamvo  Old value of diamv.
$endif
c  dlev    location of two-phase mixture level
c  dlevo   location of two-phase mixture level (old time)
c  vlev    velocity of two-phase level movement
c  vollev  Position of level within volume.
c  voidla  void fraction above the mixture level
c  voidao  void fraction above the mixture level (old time)
c  voidlb  void fraction below the mixture level
c  voidbo  void fraction below the mixture level (old time)
c  dfront    location of thermal front
c  dfrnto   location of thermal front (old time)
c  vfront    velocity of thermal front
c  ufla  liquid internal energy above the thermal front
c  ufao  liquid internal energy aaove the thermal front (old time)
c  uflb  liquid internal energy below the thermal front
c  ufbo  liquid internal energy below the thermal front (old time)
```

Figure B-3 Listing of common block VOLDATC from program ATHENA. (Continued)